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The mineral industry of the British Empire



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# IMPERIAL MINERAL RESOURCES BUREAU.

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## THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

FOREIGN COUNTRIES.

WAR PERIOD.

## SULPHUR AND IRON-PYRITES. (1913-1919.)



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IMPERIAL MINERAL RESOURCES  
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## PREFACE.

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The following digest of statistical and technical information relative to the production and consumption of sulphur and iron-pyrites will constitute a part of the Annual Volume on the Mineral Resources of the British Empire and Foreign Countries.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health, and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year. Resort will also be had to graphical representation of statistics of production, consumption, costs, and prices.

The weights are expressed in long tons, that is to say the British statute ton of 2,240 lb., and values in pounds, shillings, and pence at par rates of exchange.

Sir Herbert Jackson, K.B.E., a Governor of the Imperial Mineral Resources Bureau, is Chairman of the Advisory Technical Committee that deals with sulphur and iron-pyrites. The Bureau is indebted to Messrs. N. Garrod Thomas and A. N. Gray for their assistance in the preparation of this digest.

R. A. S. REDMAYNE,

*Chairman of the Governors.*

2, Queen Anne's Gate Buildings,

London, S.W.1.

September, 1921.

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(1913—1919).

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# SULPHUR.

## GENERAL.

Sulphur (brimstone) is a brittle and pale-yellow, non-metallic element, having a hardness of 2 and a specific gravity of about 2.05. It occurs naturally in a free state, usually mixed with limestone and other mineral matter. It melts at a temperature of about 115°C.

Native (*i.e.*, naturally-occurring) sulphur occurs abundantly in the regions that have been; or are, subjected to volcanic action. It is found encrusting fumaroles and other volcanic vents; in sulphurous springs, where it falls to the bottom as light-coloured mud; and in many old crater lakes, where the bottom is frequently covered with sulphur-bearing muds and clays. The sulphur of commerce, however, is obtained chiefly from sedimentary strata, in which the sulphur is usually associated with bituminous limestone and gypsum.

Sulphur occurs chemically combined with numerous metals as sulphides, but these compounds are of little importance as a source of crude sulphur. By the Hall process, solid sulphur containing, from 98 to 99.5 per cent. of the element has been obtained from a great variety of sulphide ores, but sulphur dioxide, largely used in the manufacture of sulphuric acid, is by far the most valuable sulphur product obtained from such ores.

For the purpose of sulphuric acid manufacture, large quantities of iron-pyrites are mined or imported annually by all the chief industrial countries of the world. In addition, attention is now being more and more directed towards utilizing the sulphur dioxide given off abundantly during the metallurgical treatment of the various sulphide ores of copper, lead, and zinc.

In the United States the sulphur dioxide given off during the roasting of sulphide ores is utilized for the manufacture of acid to a much greater extent than in the United Kingdom, as will be seen from the comparative tables given below.

The figures in these tables relating to the United States are from Bulletin No. 184 of the Bureau of Mines, Washington, U.S.A., and those relating to the United Kingdom from private sources.

### United Kingdom.

Year.	Acid made (100% $H_2SO_4$ ). Long tons.	Percentage made from—				
		Pyrites.		Spent Oxide.	Brimstone.	Zinc and Copper- Fumes.
		Imported.	Domestic.			
1914	1,082,000	88.5	0.45	10.6	0.3	0.15
1917	1,382,000	79.9	0.7	11.0	8.1	0.30
1918	1,130,000	79.4	1.6	11.2	7.4	0.40

*United States.*

Year.	Acid made (100% $H_2SO_4$ ).  Long tons.	Percentage made from—					
		Brim- stone.	Pyrites.			Zinc Ores.	Copper Smelting Waste Gases.
			Spanish.	Domestic.	Canadian		
1914	2,112,000	2·6	50·0	15·8	7·9	13·2	10·5
1917	3,982,000	32·6	22·9	11·8	6·9	18·1	7·7
1918	4,201,000	48·0	7·6	12·7	7·5	16·1	8·1

During the war the Schaffner-Helbig process of sulphur production was worked in Germany. Anhydrite (calcium sulphate) was the raw material used, and the product was exceptionally pure, containing 99·95 per cent. of sulphur. By the end of 1919 about 22,300 tons of this material had been produced in Germany from two factories.

Gypsum (hydrated calcium sulphate) was also utilized by many German sulphuric acid makers as a source of sulphur dioxide.

Sulphur is prepared for the market by heating the sulphur-bearing material to a temperature at which the sulphur will melt. It is then run into moulds, allowed to cool, and broken into lumps. This product is known as "brimstone," or, if cast into cylindrical sticks, as "roll sulphur." When a higher temperature is used, the sulphur volatilizes and may be recovered by condensation. The sulphur thus prepared is known as "flowers of sulphur" or "sublimed sulphur."

Crude sulphur is used largely in the preparation of wood-pulp for paper-making, and as a fertilizer and insecticide in agriculture. During the war there was a large increase in the amount of crude sulphur used in the manufacture of sulphuric acid. The burners required for sulphur could be erected much more easily than those for pyrites; moreover, the comparative purity of sulphur, especially as regards arsenic and volatile metals, renders it more suitable than pyrites for use in the contact process for the manufacture of sulphuric acid.

Sulphur is used in the manufacture of gunpowder, of which it usually constitutes about 10 per cent.; it is also used for vulcanizing rubber, for medicinal purposes, as a cement (for which purpose it is mixed with sand), as a vehicle for corrosive liquids, in the manufacture of matches and fireworks, in tanning, sugar-refining, glue-making, and the bleaching of cotton goods.

### WORLD'S PRODUCTION.

The greater part of the world's supply of sulphur is obtained from the United States, Italy and Japan. Sulphur is known to occur and has been worked in many other countries, notably Spain, Turkey, Mexico and Chile, but the total output from these sources is small.

The outstanding feature in the sulphur industry during the period under review was the great advance recorded in the sulphur production of the United States, due partly to the large demand for sulphur caused by the war, and partly to reduced importation of pyrites.

War conditions and competition with the United States output were largely responsible for the diminished production in Italy, but other causes operated. Many of the Sicilian mines have now reached a depth at which mining operations are no longer profitable, and they have consequently been shut down. No new deposits appear to have been opened up, and the industry generally suffers from the lack of capital and mining enterprise.

The Japanese production increased substantially during the war, the output of refined sulphur rising to the record figure of 116,191 tons in the year 1917, but, with the slackening of demand due to the armistice, production fell to approximately pre-war level.

Sulphur has been obtained in Iceland, but no information as to production and export is available in recently published trade returns.

*World's Production of Sulphur*  
(long tons).

—	1913.	1914.	1915.	1916.	1917.	1918.	1919.
<b>Austria—</b>							
Sulphur rock ... ..	10,391	19,992	3,110				10,000
<b>France—</b>							
Sulphur rock .. ...	648	—	382	689	728	4,132	
Sulphur content ... ..		—	38	69	73	556	
<b>Italy—</b>							
Crude sulphur (fused)... ..	380,101	371,771	352,352	265,045	208,442	230,531	222,492
"    "    " (ground) .. ..	19,773	25,302	21,777	18,292	17,934	18,787	28,721
Refined " .. ...	149,275	146,701	114,488	*	*	*	*
<b>Spain—</b>							
Sulphur rock ... ..	61,646	46,422	28,472	46,169	83,613	71,197	86,146
Refined sulphur † ... ..	7,378	7,930	9,515	10,459	12,678	12,533	11,261
<b>United States—</b>							
Crude sulphur ... ..	491,080	417,690	520,582	649,683	1,134,412	1,353,525	1,190,575
<b>Chile—</b>							
Sulphur rock .. ...	6,540	9,847	9,612	14,640	18,638	19,243	18,606
<b>Japan—</b>							
Sulphur rock ... ..		8,694	16,896	21,142	13,360	20,810	16,497
Refined sulphur ‡ ... ..	58,493	72,924	71,046	104,677	116,191	63,671	49,817
<b>Formosa—</b>							
Sulphur rock ... ..	2,268	1,184	1,353	2,940	2,846		

NOTE.—Java is reported to have produced about 1,200 tons of sulphur in 1913; there was no production during the period 1914 to 1917. The only recorded production in Greece was 5,306 tons in 1918 and 2,202 tons in 1919.

\* Not reported.

† From the treatment of sulphur rock in Spain.

‡ Additional to the sulphur rock mined.

BRITISH EMPIRE.

**United Kingdom.**

Native sulphur occurs sparingly within the United Kingdom. It is found associated with gypsum at Newark in Nottingham and in other counties, and as concretions in the Carboniferous Limestone of Ireland, but there are no deposits of economic importance.

Both gypsum and anhydrite occur abundantly in England, notably in the Keuper marls, but only gypsum is mined, the anhydrite being a waste product. In view of the production of sulphur and sulphur dioxide from such minerals in Germany, the English deposits may become valuable as sources of these important industrial products.

Although there is no production of native sulphur in the United Kingdom, it may be noted that there has been a considerable output of by-product sulphur, partly in the Chance-Claus process, and partly in the purification of coal-gas.

Until very recently, large quantities of sulphur have been prepared in England by the Chance-Claus process. No accurate statistics exist, but a fair estimate of the amount produced immediately prior to the war, and during the first two or three years of the war, would be 24,000 tons annually. The sulphur made in this way is comparatively pure, and commands a good price.

The law imposes upon a seller of coal-gas the obligation to remove the sulphur therefrom. The usual method of effecting this purification is by passing the crude coal-gas through purifiers consisting of shelves on which are spread layers of material containing hydrated iron oxide. This material may be bog iron-ore or an artificial preparation obtained by mixing precipitated hydrated iron oxide with an inert opening material such as sawdust.

The sulphuretted hydrogen in the coal-gas reacts on the ferric hydrate with the formation of ferric sulphide and water. The presence of a certain amount of oxygen in the coal-gas ensures oxidation of the ferric sulphide, ferric hydrate being formed, and free sulphur liberated.

The purifying material will remain in operation for 1, 2, or 3 years, at the end of which period the "spent oxide" is replaced by fresh material. The spent oxide consists essentially of a mixture of ferric hydrate and free sulphur, and the sulphur may amount to from 30 to 65 per cent. of the total weight, an average figure being 50 per cent. In addition a certain amount of tar, ammonium sulphate, and cyanogen in the form of Prussian blue and sulphocyanides are also found in spent oxide.

There appear to be no accurate figures as to the production of spent oxide, but a very close approximation of the average amount formed each year may be obtained in two ways, firstly, from an estimate of the sulphur in the crude gas made together with the knowledge of the tonnage of coal used in the gas industry, and secondly, from a knowledge of the amount of spent oxide utilized in the sulphuric acid industry. As both these methods of estimation lead to almost identical results, the following table, compiled mainly from information collected by the Explosives Department of the Ministry of Munitions, will give an accurate basis for close estimation of the amount of sulphur obtained annually in this way.

*Spent oxide (50 per cent. sulphur).*

Stock at sulphuric acid makers' works :— Long tons.  
 1st January, 1913 ... .. 32,000

Used by sulphuric acid makers during :—

1913	...	...	...	...	...	105,000
1914	...	...	...	...	...	108,000
1915	...	...	...	...	...	111,000
1916	...	...	...	...	...	127,000
1917	...	...	...	...	...	119,900
1918	...	...	...	...	...	106,100
1919	...	...	...	...	...	109,000

Stock at sulphuric acid makers works :—

31st December, 1919 ... .. 52,000

Almost the whole of the spent oxide purchased is utilized in the sulphuric acid industry. From a small amount, however, the sulphur is extracted by carbon bisulphide which is subsequently recovered by evaporation. The residual "recovered sulphur" contains the original tarry matter in the spent oxide and is a very suitable material for the manufacture of sulphuric acid.

In addition a very small amount of the spent oxide is treated for the recovery of blue, *i.e.*, ferrocyanides, but the spent oxide that has been so treated is in almost all cases used subsequently in the manufacture of sulphuric acid.

*Imports of Sulphur into the United Kingdom.\**

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Italy ... ..	15,763	12,194	35,298	33,755	17,149	60,146	7,225
United States ...	1,225	7,849	115	131	12,128	12,573	344
Other Foreign Countries.	1,226	1,756	142	144	115	1	—
Total from Foreign Countries.	18,214	21,799	35,555	34,030	29,392	72,720	7,569
Total from British Possessions.	—	—	—	—	—	—	5
TOTAL ...	18,214	21,799	35,555	34,030	29,392	72,720	7,574
	Value (£).						
Italy ... ..	81,203	67,076	204,026	295,340	230,498	913,213	133,238
United States ...	5,326	31,650	556	1,278	57,454	60,687	5,171
Other Foreign Countries.	6,183	8,859	907	1,458	2,093	20	—
Total from Foreign Countries.	92,712	107,585	205,489	298,076	290,045	973,920	138,409
Total from British Possessions.	—	—	—	—	—	—	135
TOTAL ...	92,712	107,585	205,489	298,076	290,045	973,920	138,544

\* Annual Statements of the Trade of the United Kingdom.

*Exports of Sulphur from the United Kingdom.  
(Foreign Produce.)*

To	Quantity (long tons).						
	1913.	1914.	1915.	1916	1917.	1918.	1919.
Union of South Africa ...	77	131	1,689	2,095	18	3	61
Other British Possessions	202	232	173	129	9	6	82
Total to British Possessions.	279	363	1,862	2,224	27	9	143
Norway ... ..	—	—	1	283	—	—	174
Portugal ... ..	—	—	1	4	—	4	813
Russia ... ..	—	—	521	5,064	1,174	—	32
Sweden ... ..	—	252	—	65	25	—	—
Canary Islands ... ..	48	16	39	86	—	—	—
United States ... ..	349	109	1	98	—	—	—
Other Foreign Countries	44	137	626	702	38	17	279
Total to Foreign Countries.	441	514	1,189	6,302	1,237	21	1,298
TOTAL ... ..	720	877	3,051	8,526	1,264	30	1,441
Value (£).							
Union of South Africa ...	533	942	11,110	17,241	361	112	2,305
Other British Possessions	1,284	1,702	1,734	1,589	216	195	1,716
Total to British Possessions.	1,817	2,644	12,844	18,830	577	307	4,021
Norway. ... ..	—	—	18	3,343	—	—	2,905
Portugal ... ..	—	—	9	47	—	137	18,254
Russia ... ..	—	—	4,091	60,298	17,558	—	965
Sweden ... ..	—	1,349	—	557	545	—	—
Canary Islands ... ..	298	106	248	1,073	—	—	—
United States ... ..	2,119	603	10	808	—	—	—
Other Foreign Countries	362	1,037	4,565	5,742	688	434	7,617
Total to Foreign Countries.	2,779	3,095	8,941	71,868	18,791	571	29,741
TOTAL ... ..	4,596	5,739	21,785	90,698	19,368	878	33,762

**Egypt.\***

Sulphur, associated with gypsum and anhydrite, occurs abundantly at several localities on the Red Sea coast. It was worked formerly at Ras Jemsa, 170 miles south of Jemsa. Only the richer and easily worked portions of the deposit were mined, and when these were exhausted the mines were abandoned.

There was no recorded production of sulphur in Egypt during the period under review.

**Union of South Africa.†**

In the year 1913 sulphuric acid was manufactured in South Africa chiefly from Sicilian sulphur and imported Spanish pyrites.

\* Note on the Mineral Resources of Egypt, Dept. Mines, 1914.

† The Sulphuric Acid Industry, by M. Rindl; The S. Afr. Journ. Ind., Pretoria, 1919, 2, No. 2, 125-134. Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia (Annual).

Only one company used the auriferous pyrites produced as a by-product during dressing operations at several of the Transvaal gold mines.

The difficulty of procuring supplies of imported sulphur during the war caused attention to be directed to South African sources of supply. The deposits of sulphur known to exist along the coast near Walvis Bay and Conception Bay were examined. In these districts the sulphur occurs as boulders varying from 1 foot to 4 feet in diameter, embedded in a stratum of white sand. The boulders contain 72 per cent. of free sulphur and 20 per cent. of silica, with no arsenical compounds. Owing to the limited area covered by these occurrences the deposits are not considered to be of any commercial value.

Native sulphur has recently been discovered near the mouth of the St. John's River, Griqualand East, but sufficient exploratory work has not been done to prove the value of the deposit.

*Imports of Sulphur Rock (including Iron-Pyrites) into the Union of South Africa.*

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	1	—	1	—	36	2	—
Germany ...	—	—	—	—	—	—	—
Italy ...	11,186	3,429	8,946	3,294	470	—	26
Spain ...	9,263	—	3,571	17,709	8,427	—	1
Madagascar ...	—	—	—	—	2	—	121
United States ...	—	62	—	1,964	5,937	5,185	6,016
China ...	—	—	—	—	—	150	—
Japan ...	—	—	—	—	1,615	1,473	—
Total from Foreign Countries	20,449	3,491	12,517	22,967	16,451	6,808	6,164
TOTAL ...	20,450	3,491	12,518	22,967	16,487	6,810	6,164
	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	6	6	3	—	295	35	15
Germany ...	—	3	—	—	—	—	—
Italy ...	52,406	11,483	45,306	16,502	6,076	—	959
Spain ...	8,300	—	3,200	16,594	7,650	—	17
Madagascar ...	—	—	—	—	7	—	421
United States ...	—	496	—	9,213	31,239	37,990	38,933
China ...	—	—	—	—	—	2,761	—
Japan ...	—	—	—	—	18,450	21,003	—
Total from Foreign Countries.	60,706	11,982	48,506	42,309	63,422	61,754	40,330
TOTAL ...	60,712	11,988	48,509	42,309	63,717	61,789	40,345

*Imports of Flowers of Sulphur into the Union of South Africa.*

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	398	253	282	237	6	11	104
India ... ..	—	—	—	—	—	—	—
Total from British Possessions.	398	253	282	237	6	11	104
Belgium ... ..	63	24	—	—	—	—	—
France ... ..	—	—	—	—	—	—	—
Germany... ..	51	3	—	—	—	—	—
Italy ... ..	1,873	677	658	2,765	85	1	36
Algeria ... ..	1	—	—	—	—	—	—
United States ...	—	41	76	132	442	168	49
Chile ... ..	—	—	3	—	—	—	—
Japan ... ..	—	—	—	—	270	2,565	254
Total from Foreign Countries.	1,988	745	737	2,897	797	2,734	339
TOTAL ... ..	2,386	998	1,019	3,134	803	2,745	443
	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	4,334	2,791	2,679	3,277	153	382	3,032
India ... ..	—	—	—	—	—	—	2
Total from British Possessions.	4,334	2,791	2,679	3,277	153	382	3,034
Belgium ... ..	540	228	—	—	—	—	—
France ... ..	—	—	2	1	2	—	—
Germany... ..	390	22	—	—	—	—	—
Italy ... ..	12,387	4,652	5,670	25,646	1,561	65	650
Algeria ... ..	23	—	—	—	—	—	—
United States ...	—	295	716	1,220	5,170	3,297	998
Chile ... ..	—	—	23	—	—	—	—
Japan ... ..	—	—	2	1	2,089	31,454	3,454
Total from Foreign Countries.	13,340	5,197	6,413	26,868	8,822	34,816	5,102
TOTAL ... ..	17,674	7,988	9,092	30,145	8,975	35,198	8,136

*Exports of Sulphur from the Union of South Africa.  
(Foreign Produce.)*

To	Quantity (cwt.).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
British East Africa ...	—	—	—	—	9	18	—
Mauritius ... ..	—	9	—	—	524	12,773	—
Nyasaland ... ..	—	—	—	—	4	—	—
South-West Africa Protectorate	—	—	19	31	37	18	98
Zanzibar ... ..	36	—	40	—	—	—	—
Total to British Possessions	36	9	59	31	574	12,809	98
Belgian Congo ... ..	1	1	3	4	—	31	1
Portuguese East Africa ...	44	91	110	19	1,862	7,511	110
Portuguese West Africa ...	—	—	—	—	—	—	2
Total to Foreign Countries	45	92	113	23	1,862	7,542	113
TOTAL ... ..	81	101	172	54	2,436	20,351	211
Ship's Stores ... ..	—	—	1	—	—	—	—
	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
British East Africa ...	—	—	—	—	25	38	—
Mauritius ... ..	—	7	—	—	603	8,704	—
Nyasaland ... ..	—	—	—	—	6	—	—
South-West Africa Protectorate	—	—	15	28	50	35	143
Zanzibar ... ..	17	—	8	—	—	—	—
Total to British Possessions	17	7	23	28	684	8,777	143
Belgian Congo ... ..	1	1	4	3	—	45	5
Portuguese East Africa ...	17	65	80	18	3,439	10,764	138
Portuguese West Africa ...	—	—	—	—	—	—	4
Total to Foreign Countries	18	66	84	21	3,439	10,809	147
TOTAL ... ..	35	73	107	49	4,123	19,586	290
Ship's Stores ... ..	—	—	2	—	—	—	—

*Note* :—The only exports of sulphur (domestic produce) recorded during the period under review were made in 1918 and 1919, when 100 lb. and 140 lb. were sent to South-West Africa Protectorate. Each consignment was valued at £2.

**Canada.\***

Native sulphur occurs at many localities in the provinces of Nova Scotia, Ontario, Alberta, and British Columbia, and in the district of Mackenzie; but very little attention has been given to these deposits, and no production of sulphur was recorded during the period under review.

Canada imports large quantities of sulphur from the United States. A large proportion of these imports is used as a source of sulphur dioxide in the manufacture of wood-pulp, only a quarter to a third of the total tonnage of sulphur imported being used in the manufacture of sulphuric acid.

*Imports of Sulphur (Crude, Roll and Flower) into Canada.*  
(Fiscal years ending March 31.)

From	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ... ..	99	67	13	3	—	—
New Zealand ... ..	—	1	—	—	—	—
Total from British Possessions.	99	68	13	3	—	—
Germany ... ..	16	—	—	—	—	—
Italy ... ..	650	899	92	89	—	—
Spain ... ..	13	42	—	—	—	—
Switzerland ... ..	1	—	—	—	—	—
United States ... ..	23,292	34,905	31,130	70,725	65,894	86,814
Japan ... ..	2,586	2,865	2,623	4,158	482	76
Total from Foreign Countries	26,558	38,711	33,845	74,972	66,376	86,890
TOTAL ... ..	26,657	38,779	33,858	74,975	66,376	86,890
	Value (£).†					
	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ... ..	610	318	102	82	—	—
New Zealand ... ..	—	7	—	—	—	—
Total from British Possessions.	610	325	102	82	—	—
Germany ... ..	88	—	—	—	—	—
Italy ... ..	3,383	5,002	558	537	—	—
Spain ... ..	72	216	—	—	—	—
Switzerland ... ..	49	—	—	—	—	—
United States ... ..	112,768	169,826	115,246	264,330	303,350	424,996
Japan ... ..	12,276	11,051	9,146	15,530	2,052	457
Total from Foreign Countries	128,636	186,095	124,950	280,397	305,402	425,453
TOTAL ... ..	129,246	186,420	125,052	280,479	305,402	425,453

\* Annual Reports on the Mineral Production of Canada. Annual Reports on the Trade of Canada.

† Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

**India.\***

The annual production of sulphuric acid in India is estimated at about 18,000 tons, the raw material being sulphur, which is imported from Sicily and Japan.

Deposits of sulphur have been reported as occurring at many localities in India, notably at Ghizri Bunder, in the province of Sind; at Golkurt, near Karghari, on the Mekran coast; and at Mawsün in the Southern Shan States.

The only important deposit that has been mined on an extensive scale is situated about 12 miles south-west of Sanni, in the Kachhi district of Kelat State, Baluchistan. In this deposit the sulphur rock, which has an available sulphur content varying from about 18 to 37 per cent., averages about 10 feet in thickness.

The mine, which was worked formerly by the Afghans, closed down about 40 years ago as the result of a fire which broke out in the workings, and it has not since been re-opened.

From investigations made by officers of the Geological Survey of India, who examined the deposit in the year 1919, there is in the deposit an estimated reserve of about 36,000 tons of sulphur rock, corresponding to slightly over 10,000 tons of sulphur.

In view of the large zinc-reduction works which it is intended to erect at Sakchi in Singhbhum to treat Burmese (Bawdwin) zinc concentrates for the production of spelter and the manufacture of sulphuric acid, there does not seem much scope for sulphur-mining in India.

*Imports of Sulphur into India.*  
(Fiscal years ending March 31.)

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	420	373	501	223	108	14	1
Hong Kong ...	—	—	—	—	—	34	—
Straits Settlements...	—	—	40	23	—	11	10
Other British Possessions.	—	—	—	—	—	—	—
Total from British Possessions.	420	373	541	246	108	59	11
Germany ...	1	15	—	—	—	—	—
Italy ...	4,006	4,459	4,159	3,978	4,721	2	—
United States ...	40	—	—	—	—	194	18
Japan ...	1,277	1,479	1,401	4,251	4,137	9,530	4,809
Other Foreign Countries.	5	1	1	3	—	—	—
Total from Foreign Countries.	5,329	5,954	5,561	8,232	8,858	9,726	4,827
TOTAL ...	5,749	6,327	6,102	8,478	8,966	9,785	4,838

\* Industrial Handbook Indian Munitions Board, 1919. Report of the Sanni Sulphur Mine, by G. de P. Cotter : Rec. Geol. Surv. India, 1919, 50, Pt. 2, 130-138; Rec. Geol. Surv. India, 1921, 52, 61 and 320-322. Statements of Sea-borne Trade of British India (Annual).

*Imports of Sulphur into India—continued.*  
(Fiscal years ending March 31.)

From	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	2,809	2,508	2,847	2,019	1,628	379	87
Hong Kong ...	—	—	—	—	—	901	—
Straits Settlements...	1	—	239	146	—	301	159
Other British Possessions.	—	—	—	2	—	2	—
Total from British Possessions.	2,810	2,508	3,086	2,167	1,628	1,583	246
Germany ...	13	144	—	—	—	—	—
Italy ...	26,460	30,301	31,693	34,213	51,731	21	—
United States ...	299	—	—	—	—	3,548	329
Japan ...	6,177	6,916	6,752	22,484	35,641	106,639	67,718
Other Foreign Countries.	51	25	7	45	—	—	—
Total from Foreign Countries.	33,000	37,386	38,452	56,742	87,372	110,208	68,048
TOTAL ...	35,810	39,894	41,538	58,909	89,000	111,791	68,294

### Australia.\*

Native sulphur has been found at various localities in many parts of the Commonwealth, but most of these have proved to be of no economic importance.

Deposits of sulphur of promising character occur near Debawala in the Iamalele district, Ferguson Island, Papua, within a mile of good anchorage at Seymour Bay. The Government Geologist estimates that there are 15 to 17 acres of sulphur, averaging one foot in depth, or about 42,000 tons. Samples showed from 16 to 86 per cent. of sulphur, with an average of 58·7 per cent. The costs per ton of sulphur, mined at Iamalele and shipped to Sydney, are estimated at £8 10s.

In the year 1916 experiments were carried out at the Mount Lyell Company's works with the object of extracting before smelting a portion of the sulphur contained in sulphide ores. These investigations culminated in the construction of an experimental sulphur extraction plant, but sulphur has not yet been produced on a commercial scale at these works.

With reference to the utilization of the sulphur dioxide given off during the roasting of lead-zinc ores, *see* Pyrites section, p. 49.

\* Queensland Government Mining Journal, 1916, p. 526. Trade and Customs and Excise Revenue of the Commonwealth of Australia (Annual).

*Imports of Sulphur or Brimstone into Australia.*  
(Fiscal years ending June 30.)

From	Quantity (long tons).				
	1915.	1916.	1917.	1918.	1919.
United Kingdom ... ..	104	157	104	1	13
Union of South Africa ... ..	—	1	—	—	—
New Zealand ... ..	1	46	—	—	—
Total from British Possessions.	105	204	104	1	13
Denmark ... ..	—	20	—	—	—
Germany ... ..	59	—	—	—	—
Italy ... ..	179	12,884	16,444	—	—
United States ... ..	—	—	188	48	411
Japan ... ..	20,728	28,161	32,853	39,596	29,164
Philippine Islands ... ..	—	—	—	—	15
Other Foreign Countries ... ..	4	13	—	—	—
Total from Foreign Countries.	20,970	41,078	49,485	39,644	29,590
TOTAL ... ..	21,075	41,282	49,589	39,645	29,603
	Value (£).				
	1915.	1916.	1917.	1918.	1919.
United Kingdom ... ..	1,217	2,214	1,787	28	467
Union of South Africa ... ..	—	13	—	—	—
New Zealand ... ..	10	660	—	—	—
Total from British Possessions.	1,227	2,887	1,787	28	468*
Denmark ... ..	—	186	—	—	—
Germany ... ..	414	—	—	—	—
Italy ... ..	1,509	70,637	115,860	3	—
United States ... ..	—	—	2,075	558	6,550
Japan ... ..	101,159	145,947	300,111	310,315	238,787
Philippine Islands ... ..	—	—	—	—	371
Other Foreign Countries ... ..	34	86	—	—	—
Total from Foreign Countries.	103,116	216,856	418,046	310,876	245,908
TOTAL ... ..	104,343	219,743	419,833	310,904	246,376

\* Including sulphur valued at £1 imported from Solomon Islands.

*Exports of Sulphur from Australia (Foreign Produce).*  
*(Fiscal years ending June 30.)*

To	Quantity (cwt.).				
	1915.	1916.	1917.	1918.	1919.
New Zealand ... ..	—	124	396	1,833	—
British Pacific Possessions ... ..	—	65	—	—	—
Other British Possessions ... ..	85	—	38	49	—
Total to British Possessions ...	85	189	434	1,882	—
Foreign Pacific Possessions ...	4	9	8	8	—
TOTAL ... ..	89	198	442	1,890	—
Value (£).					
New Zealand ... ..	—	100	328	1,174	—
British Pacific Possessions ... ..	—	52	—	—	—
Other British Possessions ... ..	64	—	40	47	—
Total to British Possessions ...	64	152	368	1,221	—
Foreign Pacific Possessions ...	3	8	8	9	—
TOTAL ... ..	67	160	376	1,230	—

**New Zealand.\***

Sulphur is mined on a small scale in New Zealand in the districts around Lake Rotorua, towards the centre of the North Island, where the sulphur occurs in pockets in a volcanic sinter, or in surface deposits in the vicinity of fumaroles and thermal springs. The only outputs recorded during the period under review are 466 tons and 1,120 tons for 1916 and 1917 respectively. The total output from the Rotorua region up to the end of 1917 amounted to 4,841 tons of crude sulphur.

In the year 1913 the New Zealand Sulphur Company commenced sulphur-mining operations on an important scale on White Island, a volcanic cone in the Bay of Plenty (to the north-east of the Rotorua region), where there were extensive sulphur-bearing beds underlying the crater lake. Draining operations were put in hand, and a sulphur-refining plant installed, but in the following year a violent eruption of the crater destroyed the deposit, and the undertaking was abandoned.

From 1898 to 1902 New Zealand exported 4,927 tons of sulphur, valued at £13,239. Since 1902 the small quantity of sulphur

\* New Zealand Mines Statements (Annual). New Zealand Official Year Book for 1919. Trade and Shipping of New Zealand (Annual).

produced has been used locally at chemical works. Owing to the nature of the deposits, and to transport difficulties, it is unlikely that sulphur can be exported at a price allowing of competition with United States, Italian, and Japanese supplies.

*Imports of Sulphur into New Zealand.*

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	15	25	24	13	1	2	9
Australia ... ..	4	3	157	3	73	85	142
Total from British Possessions.	19	28	181	16	74	87	151
Germany ... ..	5	10	—	—	—	—	—
Italy ... ..	52	69	66	19	—	—	—
Sweden ... ..	—	2	—	—	—	—	—
United States ... ..	—	—	2	19	7	4	23
Japan ... ..	1,848	—	1,465	2,390	1,780	2,989	3,060
Total from Foreign Countries.	1,905	81	1,533	2,428	1,787	2,993	3,083
TOTAL ... ..	1,924	109	1,714	2,444	1,861	3,080	3,234
	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom ...	123	289	225	281	35	166	300
Australia ... ..	40	25	921	50	1,009	1,688	2,006
Total from British Possessions.	163	314	1,146	331	1,044	1,854	2,306
Germany ... ..	41	81	—	—	—	—	—
Italy ... ..	408	594	691	261	—	—	—
Sweden ... ..	—	16	—	—	—	—	—
United States ... ..	—	—	67	303	203	73	368
Japan ... ..	9,905	—	7,057	8,756	14,091	19,780	32,161
Total from Foreign Countries.	10,354	691	7,815	9,320	14,294	19,853	32,529
TOTAL ... ..	10,517	1,005	8,961	9,651	15,338	21,707	34,835

FOREIGN COUNTRIES.

**France.\***

Sulphur-bearing marls are mined in the departments of Bouches-du-Rhône and Vaucluse for use in the vineyards, and there is a small deposit of native sulphur, associated with gypsum, which is mined at Biabaux near Marseilles.

\* Statistique de l'Industrie Minérale en France et en Algérie (1914-1918). Le Commerce de la France (Annual).

*Production of Sulphur in France.*

Year.	Sulphur Rock.		Sulphur Content.	
	Quantity		Quantity	
	(long tons).		(long tons).	
1913	...	...	648	—
1914	...	...	—	—
1915	...	...	382	38
1916	...	..	689	69
1917	...	...	728	73
1918	...	...	4,132	556
1919	...	...		

*Imports of Sulphur into France.*

Year.	Crude (including rock).		Refined (in sticks, etc.)†		Sublimate (flowers of sulphur).†	
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).
1913 ...	183,349	819,920				
1914 ...	113,921	521,000				
1915 ...	97,798	667,920				
1916 ...	115,017	1,589,800	8,461	154,800	2,558	52,000
1917 ...	56,533	1,264,040	14,751	479,760	4,347	159,040
1918 ...	49,901	1,014,320	15,089	460,040	6,412	221,560
1919 ...	108,278	2,200,960	22,220	677,480	7,228	249,760

*Exports of Sulphur from France.*

Year.	Crude (including rock).		Refined (in sticks, etc.).		Sublimate (flowers of sulphur).	
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).
1913 ...	10,146	45,360	2,461	14,000	10,342	67,280
1914 ...	1,861	8,520	1,199	7,320	11,344	76,080
1915 ...	949	6,480	2,387	24,280	8,086	85,480
1916 ...	2,798	38,680	3,432	62,800	10,793	219,400
1917 ...	2,785	62,280	608	19,760	2,050	75,040
1918 ...	1,228	24,960	307	9,360	2,061	71,240
1919 ...	1,472	29,920	490	14,960	2,354	81,320

**Italy.†**

Italy is the most important sulphur-producing country in Europe, and ranks in production second to the United States.

During the period under review the costs of sulphur-production in Italy increased, and the output declined very considerably.

\* Values converted to £ sterling at the rate of 25 francs = £1.

† Not stated prior to 1916.

‡ Rivista del Servizio Minerario (Annual).

Before the war sulphur was mined at about 80 lire\* per ton, but by the end of 1920 the cost had risen to 650 lire. High wages, shortage of labour and lack of new machinery have all contributed to the increase of mining costs, while the scarcity of fuel has led to the employment of wasteful methods of sulphur recovery. In former times, Italian sulphur found a wide market in European countries, but it is now difficult for Italian producers to compete successfully with those of the United States, and the export market is practically limited to the wine-producing countries of Southern Europe, where large quantities of sulphur are used in the vineyards.

About 10 per cent. of the total Italian production of sulphur is obtained from the mainland, where sulphur mines are being worked near the towns of Rimini and Pesaro, on the Adriatic coast. There is also a small production from a mine on the east coast of Southern Calabria.

The bulk of the sulphur produced is obtained in Sicily, where the sulphur-bearing belt extends from Mount Etna on the east to Girgenti on the west, a distance of more than 100 miles. The width of this belt averages about 55 miles. The centre of the Sicilian sulphur-mining industry is at Caltanissetta. In the deposits of this region the sulphur occurs associated with gypsum and bituminous marls, as veins, pockets and impregnations in limestone beds of Miocene age. These sulphur-beds vary in thickness from 3 feet to 8 feet, and in some localities up to nearly 100 feet, three or four beds being usually present in each deposit. Calcite and celestite frequently accompany the sulphur. The yield varies from about 8 per cent. to 40 per cent. of the rock as mined, but individual deposits are known with 50 per cent., and in places, notably at Naro, 80 to 90 per cent. rock is not uncommon. The average sulphur content of the rock is about 25 per cent. The sulphur rock is usually contaminated with bitumen, clay and other impurities, and requires refining before shipment.

*Italian Production, Imports and Exports of Crude and Ground Sulphur.*

Year.	Production.			Imports.	Exports.
	Crude (fused) (long tons).	Crude (ground) (long tons).	Refined † (long tons).	Total (long tons).	Total (long tons).
1913	380,101	19,773	149,275	180	345,692
1914	371,771	25,302	146,704	103	256,149
1915	352,352	21,777	114,488	290	387,577
1916	265,045	18,292		703	321,189
1917	208,442	17,934		3	116,438
1918	230,531	18,787		—	189,138
1919	222,492	28,721		2,579	118,522

\* At par, 25 lire = £1.

† Not reported after 1915.

*Output of Sulphur in the District of Caltanissetta, Sicily.*

Year.	Rock raised.		Material treated.	Sulphur obtained from material treated.	
	Quantity (long tons).	Value at mines * (£).	Quantity (long tons).	Quantity (long tons).	Value * (£).
1913	2,175,084	999,232	2,230,576	342,002	1,085,324
1914	2,083,886	1,011,476	2,194,025	331,812	1,098,865
1915	1,965,775	1,020,305	2,066,384	317,071	1,110,369
1916	1,449,513	1,229,486	1,543,473	232,493	1,306,734
1917	1,134,736	2,146,526	1,179,800	180,215	2,235,994
1918	1,335,358	2,994,273	1,344,804	199,482	3,113,710
1919	1,389,412	2,603,863	1,392,754	188,996	2,792,004

*Exports of Sulphur from the District of Caltanissetta, Sicily.*

To	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom and Malta	15,778	12,782	35,572	68,059	19,790	61,589	3,836
Australia ...	13,224	1,612	326	23,220	—	—	—
Other British Possessions	6,249	5,463	5,742	6,355	344	1,487	835
Total to British Possessions	35,251	19,857	41,640	97,634	20,134	63,076	4671
France ...	73,977	60,879	94,609	105,586	67,463	88,924	67,922
Germany ...	31,454	18,521	385	—	—	—	374
Greece ...	14,380	15,505	19,539	14,820	382	7,468	15,212
Portugal ...	14,011	11,464	12,578	13,768	4,032	7,342	—
Russia ...	25,690	18,069	2,746	19,626	6,473	—	301
Other Foreign Countries	133,122	92,926	67,800	62,964	9,868	17,306	25,462
Total to Foreign Countries	292,634	217,364	197,657	216,764	88,218	121,040	109,271
TOTAL ...	327,885	237,221	239,297	314,398	108,352	184,116	113,942
Mainland of Italy ...	71,817	88,391	107,166	66,931	42,368	38,822	29,029

**Spain.†**

Deposits of sulphur associated with gypsum and marl are mined in the provinces of Murcia, Almeria and Albacete. During the war there was considerable activity in the sulphur-mining industry, but no new deposits of importance appear to have been discovered, and the total output is insufficient to meet the domestic demand.

\* Values converted to £ sterling at the rate of 25 lire = £1.

† Estadística Minera de España (Annual). Estadística General del Comercio Exterior de España (Annual).

*Production of Sulphur-Rock and Sulphur in Spain.*

Year.		Sulphur Rock. Quantity (long tons).	Sulphur. Quantity (long tons).
1913	...	61,646	7,378
1914	...	46,422	7,930
1915	...	28,472	9,515
1916	...	46,169	10,459
1917	...	83,613	12,678
1918	...	71,197	12,533
1919	...	88,146	11,261

*Imports and Exports of Sulphur into and from Spain.*

Year.	Imports.			Total Exports of sulphur (long tons).	
	Raw sulphur unground (long tons).	Refined sulphur, unground (long tons).	Refined sulphur, ground and flowers of sulphnr (long tons).		
1913	...	2,141	1,208	6,879	2
1914	...	906	1,415	7,860	5
1915	...	1,259	1,072	6,246	1
1916	...	1,761	1,941	7,910	1
1917	...	114	75	1,727	34
1918	...	—	1,165	2,993	235
1919	...	3,252	13	6,272	403

**United States.\***

Sulphur deposits have been worked in many parts of the United States, but more than 98 per cent. of the total output has been obtained from the deep-lying sulphur-bearing beds of Louisiana and Texas. On these fields the sulphur is melted *in situ* underground by means of superheated water (Frasch process). The liquefied sulphur collects at the bottom of the wells bored into the deposit and is forced by air-lifts to the surface, where it is piped to bins in which it consolidates on cooling. Many wells are now drilled in these localities to a depth of 800 to 1,000 feet, the diameter being commonly about one foot. The sulphur obtained by this method is remarkably pure (about 99·5 sulphur) and requires no further treatment at the mines before shipment, all that is necessary being to break up the consolidated material in the bins, by blasting with powder, and load it into cars. The chief centres of the sulphur-mining industry are near Freeport, in Brazoria county, and Gulf, in Matagorda county, Texas; and at the sulphur mine in Calcasieu parish, Louisiana. The most productive wells in these regions are stated to have yielded more than 100,000 tons of sulphur.

\* Annual Reports on the Mineral Resources of the United States. The Mineral Industry (Annual).

The sulphur obtained in this way almost invariably contains as an impurity a small amount of oil (about 0.1 per cent.), and it is interesting to note that even this small amount has a considerable effect upon the burning quality of the sulphur. If a pool of this sulphur is left to burn unstirred, the oil rises to the surface and forms a kind of asphalt, which hinders the burning of the remainder of the sulphur. The difficulty is, however, easily overcome by agitating the burning sulphur.

Since 1913 production of sulphur in Texas has increased greatly, and the United States now ranks first among the sulphur-producing countries. This expansion of output was caused by the increased demand for sulphur, arising partly from war conditions and partly from the stoppage of the import of Spanish pyrites. Sulphuric acid manufacturers in the United States were compelled during the war to turn for their requirements of the raw material to the domestic supplies of crude sulphur. Many of them have permanently equipped their plants to burn sulphur, and it seems probable that crude sulphur will continue to compete successfully with pyrites in the manufacture of sulphuric acid in the United States, at any rate in the south, and at points remote from ports.

*Production of Sulphur in the United States. .*

Year.	Production.	Despatched from mine:	
	Quantity (long tons).	Quantity (long tons).	Approximate Value* (£).
1913 ... ..	491,080	319,333	1,170,208
1914 ... ..	417,690	341,985	1,294,583
1915 ... ..	520,582	293,803	1,033,125
1916 . . . .	649,683	766,835	2,551,250
1917 ... ..	1,134,412	1,120,378	4,997,292
1918 ... ..	1,353,525	1,266,709	5,805,833
1919 ... ..	1,190,575	678,257	2,135,833

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

*Sulphur Imported and entered for Consumption in the United States*

Year.	Crude.		Flowers of Sulphur.		Refined.		All other Kinds.†		Total.	
	Quantity. Long tons.	Value.* £	Quantity. Long tons.	Value.* £	Quantity. Long tons.	Value.* £	Quantity. Long tons.	Value.* £	Quantity. Long tons.	Value.* £
1913	15,122	59,627	5,899	24,078	1,234	6,061	350	3,686	22,605	93,452
1914	23,610	83,122	621	3,586	1,800	9,910	104	2,952	26,135	99,570
1915	24,647	84,581	647	4,822	988	6,320	85	2,706	26,367	98,429
1916	21,289	74,670	425	3,835	455	3,129	66	2,696	22,235	84,330
1917	973	4,203	—	—	—	—	42	1,909	1,015	6,112
1918	55	352	—	—	—	—	27	1,635	82	1,987
1919	77	416	—	—	—	3	24	1,379	101	1,798

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Includes sulphur lac and other grades not otherwise specified, but not pyrites.

*Exports of Sulphur from the United States.*

Year.	Quantity (long tons).			Value* (£).
1913	...	...	89,221	333,284
1914	...	...	98,163	376,526
1915	...	...	37,312	150,975
1916	...	...	128,755	522,054
1917	...	...	152,736	729,337
1918	...	...	131,092	755,550
1919	...	...	224,712	1,317,823

**Chile.†**

Chile possesses a large number of important sulphur deposits of volcanic origin, but the majority of these are situated in the western Andes at altitudes too great for systematic mining. So far as is known, the highest deposits worked are situated on Mount Olca, in the Ollagüe district, province of Antofagasta, and on Mount Chupiquiña, in the Tacora district, province of Tacora, at altitudes from 17,000 feet to 18,500 feet above sea-level. Sulphur-mining operations are confined chiefly to these two districts.

At Mount Ollagüe large quantities of pure sulphur have been deposited in the vicinity of the active vents and fumaroles. This is quarried, bagged and transported to the railway at Ollagüe. The underlying rich sulphur-bearing rock is not at present worked.

In the Tacora district mining is carried out in a less wasteful manner. The deposits are situated on Mount Chupiquiña and Mount Tacora. The sulphur-bearing rock is of lower grade, and the whole deposit is mined. The excavated material is transported to the refining centres by narrow-gauge railway or aerial tramway.

*Production of Sulphur Rock in Chile.*

Year.	Quantity (long tons).				
1913	...	...	...	...	6,540
1914	...	...	...	...	9,847
1915	...	...	...	...	9,612
1916	...	...	...	...	14,640
1917	...	...	...	...	18,638
1918	...	...	...	...	19,243
1919	...	...	...	...	18,606

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Anuario Estadístico de la Republica de Chile. Statistical Abstract of the Republic of Chile, 1918.

### Japan.\*

Japan is an important producer of sulphur. The deposits mined are invariably of volcanic origin and occur either as sulphur-bearing clays forming the beds of lakes in ancient craters, or as sulphur-bearing muds that have been ejected during periods of volcanic activity. A little sulphur is also found encrusting the rocks in the vicinity of volcanic vents and fumaroles.

The most important mining area is situated in Hokkaido, where the deposit occupies the bed of a crater lake. The product obtained is grey or yellowish in colour, and contains from 50 to 90 per cent. of sulphur. In the island of Kyushu there are sulphur mines along the Kirishima volcanic zone, and in the northern part of Honshu, the main island of Japan, there are many important deposits. There are no sulphur mines in the island of Shikoku, which lies between these two islands. In addition, sulphur is mined on a small scale in several of the Kurile Islands and in the vicinity of Daiton volcano, in Formosa. There is no production of sulphur in Korea.

There has hitherto been normally only a small demand for sulphur in Japan, and before the war practically the entire output was shipped to the United States, Australia, Canada, India, and Russia. During the war, the Japanese production of sulphur increased considerably, reaching the record figure of 116,191 tons in the year 1917, the greater part of the output being exported to Australia, India and other eastern countries. Since 1917, the production has fallen rapidly, partly owing to the decreased demand for sulphur for munition purposes, but chiefly to the inability of Japanese producers to compete successfully in the United States with the domestic product. A further cause was the very high freight rates charged on shipments from Japan to Australia during the years 1918 and 1919.

#### *Production of Sulphur and Sulphur Rock in Japan.*

Year.	Sulphur.		Sulphur Rock.	
	Quantity (long tons).	Value † (£).	Quantity (long tons).	Value † (£).
1913 ... ..	58,493	156,843	—	—
1914 ... ..	72,924	200,279	8,694	4,988
1915 ... ..	71,046	190,222	16,896	9,295
1916 ... ..	104,677	429,554	21,142	19,985
1917 ... ..	116,191	476,652	13,360	10,421
1918 ... ..	63,671	253,243	20,810	14,286
1919 ... ..	49,817	225,632	16,497	16,900

\* Statistical Reports of the Department of Agriculture and Commerce (Annual).

† Values converted to £ sterling at the rate of 10 yen = £1.

*Exports of Sulphur from Japan.*

Year.				Quantity (long tons).	Value* (£).
1913	...	...	...	53,287	198,084
1914	...	...	...	50,647	184,592
1915	...	...	...	73,537	248,763
1916	...	...	...	81,211	621,554
1917	...	...	...	83,920	614,279
1918	...	...	...	53,500	
1919	...	...	...	27,500	

*Production of Sulphur Rock in Formosa.*

Year.				Quantity (long tons).	
1913	...	...	...	...	2,268
1914	...	...	...	...	1,184
1915	...	...	...	...	1,353
1916	...	...	...	...	2,940
1917	...	...	...	...	2,846
1918	...	...	...	...	
1919	...	...	...	...	

**New Hebrides.**

Large deposits of sulphur are reported to occur in the New Hebrides, where they are in some places forming even at the present time as a result of volcanic action. The sulphur occurs partly in a pure state and partly mixed with clay.

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**APPENDIX.****THE MANUFACTURE OF SULPHUR FROM SULPHATES DURING THE WAR.**

An interesting development in connection with sulphur production during the war was its manufacture from gypsum and anhydrite in Germany.

Imports of sulphur into Germany from the main sources of supply were cut off by the war, and in 1916 the production of crude sulphur from calcium sulphate was commenced at two factories, one at Drachenburg, near Walbeck, and another at Bernburg, both within easy reach of large potash works from which supplies of magnesium chloride could be obtained.

The process employed, known as the Schaffner-Helbig process, involves the reduction of anhydrite to calcium sulphide, the disintegration of this sulphide with magnesium chloride lye to form sulphuretted hydrogen, and the conversion of the sulphuretted hydrogen into sulphur by burning.

The reduction to calcium sulphide is effected by crushing and drying the anhydrite, mixing the crushed material with dried coal, and, after re-crushing, reducing the mixture in a rotary furnace at a temperature of 1100°C. The product, containing about 70 per cent. of calcium sulphide, is then cooled.

The decomposition of the calcium sulphide is effected by adding magnesium chloride lye and heating the mixture with steam at a temperature of 70°C. until the whole of the sulphuretted hydrogen has been expelled from the liquid. The gas is then cooled and stored in a gasometer, from which it passes to the mixing chamber into which sufficient air is blown to allow the hydrogen to burn. The gas mixture is then drawn downwards through four large contact furnaces, bauxite being used as a contact material. In these furnaces a flameless burning of the hydrogen takes place, and the separation of sulphur is effected. The liquid sulphur is run off at intervals into cooling pans where it sets hard and only requires to be broken up to be ready for market.

The product obtained by this process is remarkably pure, averaging about 99.95 per cent. sulphur. The gases given off in the contact furnace are treated subsequently in a dust chamber, where a certain amount of the sulphur contained is recovered. Arrangements have been made whereby the whole of the sulphur contained in the gases from the contact furnaces is converted into sulphuric acid, thus saving the sulphur which was formerly lost up the chimney stack after leaving the dust chamber.

The principal item in the working cost is incurred in the reduction of the calcium sulphate to sulphide, about 4.5 tons being required to produce 1 ton of sulphur.

By the present method of manufacture, about 60 per cent. of the available sulphur is recovered, and it would appear to be only a matter of time before this percentage is substantially increased. By the end of 1919 about 22,300 tons of sulphur had been produced by this process at the Walbeck and Bernburg works.

The possibility of the commercial production of sulphur from sulphates is of considerable practical interest and importance. The United Kingdom, Canada and other parts of the British Empire are well provided with resources of gypsum and other sulphates, and it is important to keep in mind the fact that these could be utilized as sources of sulphur and sulphuric acid in case of emergency.

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## IRON - PYRITES. (1913-1919.)

### GENERAL.

Pyrite or iron-pyrites is a bisulphide of iron ( $\text{FeS}_2$ ). When pure and unaltered it has a brassy yellow colour, and a specific gravity of about 4.95. It contains 53.4 per cent. of sulphur and 46.6 per cent. of iron when pure, but small quantities of arsenic, copper, and other impurities are often present. Gold is frequently present, and auriferous pyrites is often a valuable gold ore. Pyrite occurs abundantly in veins or as disseminated crystals and nodules, but the deposits of chief economic importance usually occur as lenticular masses of great size, in sedimentary and crystalline rocks of all ages.

Marcasite has the same composition as pyrite, but is lighter in colour, decomposes more readily, and has a specific gravity of about 4.7. It occurs usually as nodules in sedimentary rocks, and is obtained as a by-product in coal-mining. Marcasite does not occur as a rule in deposits of large size, and is not of much commercial importance.

Pyrrhotite is a magnetic sulphide of iron of variable composition, occurring in association with basic igneous rocks such as gabbros. Pyrrhotite deposits frequently contain considerable amounts of copper, nickel and platinum, and are important as sources of those metals. At best the sulphur content does not quite reach 40 per cent., a fact which renders it, as a rule, unsuitable for sulphuric acid manufacture. However, pyrrhotite has been used for the production of acid by the contact process at Pulaski, in Virginia, United States.

The commercial value of pyrites depends chiefly upon the quantity of available sulphur and copper it contains, the ease with which the sulphur can be recovered for the manufacture of sulphuric acid, and the position of the deposit as regards cheap mining and transport facilities. Good lump pyrites may contain as much as 51 per cent. of sulphur, but material containing as little as from 35 to 40 per cent. of sulphur is marketable if its roasting quality is good. Arsenic is deleterious in the contact process; and when pyrites containing even a small percentage of that element is used in connection with this process, the arsenic must be completely removed by an elaborate cleaning system.

Upon the outbreak of the war, pyrites became a mineral of great importance. Large quantities of sulphuric acid were required for the manufacture of explosives in addition to the acid needed for normal trade requirements. At the time, pyrites was almost the only raw material used in the acid plants for the manufacture of sulphuric acid.

Increasing quantities of sulphuric acid were being produced in the United States, Germany and elsewhere, from the waste sulphur-dioxide gases given off during the preliminary roasting of zinc-blende and other sulphide ores, but these sources were

inadequate to meet the greatly increased demand for sulphuric acid. The Allies were fortunately able to maintain their supplies of pyrites from Spain, Italy and Norway during the war, and the United Kingdom was never seriously short of the mineral, in spite of the restricted shipping facilities caused by the German submarine campaign. France possessed large domestic resources but always drew on Spain, Portugal and Italy, while the Italian deposits provided an ample supply for Italian requirements, and Russia, during the period of her participation in the war, was able to supplement her domestic supplies by shipments from Japan. Before the war the United States imported annually about 1,000,000 tons of Spanish pyrites. This supply was greatly reduced by lack of cargo space and other causes, but the United States was able to meet the shortage by increased production from domestic sulphur mines and largely increased imports of Canadian pyrites. Only in the acid plants of the middle-west was there any serious difficulty in obtaining supplies, and there the deficiency was made good by substituting crude sulphur for pyrites burners in many of the acid plants. This alteration was made commercially practicable by the great output of cheap sulphur from the newly-developed sulphur wells of Texas, and it is probable that in the future crude sulphur will continue to be used in large quantities in the United States for the purpose of sulphuric acid manufacture.

The enemy countries were never short of sulphuric acid. Before the war Germany always had large stocks of Spanish pyrites, and during the first year of war she was able to eke out these stocks by importing large quantities of Norwegian pyrites, but these supplies were stopped in the year 1915. The German supplies, however, were sufficient to meet all demands until the Meggen pyrites deposits in Westphalia were adequately opened up. In addition, new and improved processes were evolved whereby the large quantities of sulphur dioxide given off during the roasting of zinc and lead ores became available for sulphuric acid manufacture. Austria obtained supplies from deposits in Hungary, and later from Serbia.

#### PRICES.

Before the war, iron-pyrites of a good burning quality containing 47 to 50 per cent. sulphur was sold at 21s. 6d. per ton c.i.f., cupreous pyrites of good quality commanded 4½d. to 4¾d. per unit c.i.f., and washed ore 18s. 6d. per ton lumps or 18s. per ton fines. These prices were based on a freight rate of about 5s. 6d. per ton. In the early stages of the war practically no change was recorded in the f.o.b. values of the various grades of pyrites, the market being if anything rather weaker owing to the rapid falling off in shipments arising from the dislocation of ordinary commercial conditions.

Again, it has to be remembered that some of the largest markets were to a considerable extent cut off from supplies, notably the enemy countries, to whom Spain, the principal producing country, shipped about one million tons during the year 1913.

The demand which arose for pyrites in the Allied countries for the manufacture of explosives early in 1915, and the falling off of the French production, very soon brought about a stiffening in prices of Spanish pyrites. When the British Government assumed control, the market prices ranged from 12s. 6d. to 25s. per ton (f.o.b.) for washed pyrites, and about 5½d. per unit of sulphur (f.o.b.) for cupreous pyrites. These prices were, however, subject to an addition if the mining companies were called upon to pay more than a certain agreed freight on coal outwards from the United Kingdom to Spain.

It should be noted that many of the larger Spanish pyrites mines are financed by British capital, and their stores and coal were in the main obtained from the United Kingdom. Some idea may be formed of the extraordinary conditions which the pyrites-mining companies were called upon to meet when it is stated that at one time freight on coal from South Wales to Spain rose to the remarkable figure of 420s. per ton, as compared with the pre-war rate of 4s. 6d. to 5s. 6d. per ton.

Following the termination of hostilities, considerable labour troubles were encountered at the pyrites mines, and one of the leading companies was for many months unable to carry on mining operations. The effect on prices was, however, not considerable, and in 1919 the average selling price was about 6½d. per unit (cupreous) f.o.b., Spanish port, iron-pyrites at the same period being about 25s. per ton f.o.b. The variation in prices of washed ore throughout the period under review was not considerable, as is shown by the fact that in 1919 sales were effected at 15s. to 18s. per ton f.o.b.

The course of prices of Norwegian pyrites during the war period cannot be regarded as an indication of its commercial value. It will be obvious that, owing to her geographical position, Norway found herself between two contending groups of belligerents, and consequently the prices paid for the Norwegian mineral were governed by diplomatic considerations. The Norwegian mining companies formed an Export Association, and an arrangement was entered into with this association to purchase the whole of Norway's surplus pyrites for the Allies after domestic needs had been met. This arrangement came to an end with the termination of hostilities.

#### IRON-PYRITES AND SULPHURIC ACID MANUFACTURE.

Iron-pyrites is almost wholly used in the production of sulphuric acid. Only a very small amount of the pyrites

imported into the United Kingdom is consumed in the manufacture of ferrous sulphide, which is used in the de-arsenication of acid, and in copper smelting as a flux.

The sulphuric acid manufacturer, in arranging for his supplies of pyrites, may either purchase the mineral outright, including any copper that may be present, or may purchase only the sulphur value, and be under the obligation of handing back the cinders produced from the burning of the pyrites either to the mine-owner or to some third party indicated. In the latter case, the terms of purchase will depend on which of these parties bears the cost of carriage of the cinders from the acid-manufacturer's works to their ultimate destination.

The sulphur value of pyrites is reckoned at so much per unit of that element per long ton, a unit being 1 per cent. or 22.4 lb. For example, pyrites containing 47.5 per cent. of sulphur at 6d. per unit would cost 23s. 9d. per long ton.

There is no aspect of pyrites, physical or chemical, which is not of importance to the sulphuric acid manufacturer, and the following is a short account of the main points of interest:—

### *Physical Considerations.*

*Size.*—Pyrites may be divided roughly into three sizes, namely, (1) "as mined," (2) "furnace size," and (3) "smalls." The first size may contain lumps sometimes weighing a cwt. or more, and is also certain to contain a large amount of small pieces which would pass through a  $\frac{1}{4}$ -inch screen. It is, therefore, unsuitable for burning on any type of burner without further grinding and grading. "Furnace size" pyrites is graded by passing through a  $2\frac{1}{2}$ -inch or 3-inch screen on to a  $\frac{1}{4}$ -inch screen. This size is specially suited for use in lump burners and for this reason commands an additional 1s. or 2s. per ton. "Smalls" consist of pyrites which pass through a small sieve,  $\frac{1}{2}$ -inch,  $\frac{3}{8}$ -inch, or  $\frac{1}{4}$ -inch mesh, according to the type of burner on which it is to be used.

*Crushing.*—The hardness of pyrites is very variable. Some varieties, particularly Norwegian, are extremely hard and wear out the jaws of a crusher very quickly. Such mineral may cost 5s. or 6s. a ton to crush. Other varieties, especially washed pyrites, are softer, and the expense is one-third to one-quarter of that for the hard variety. When the mineral has to be finely ground, its physical character is of great importance. Some kinds crush to a very fine powder, with the result that in the burners a considerable proportion is carried over by the draught, and contaminates the acid with iron. Other kinds crush to a heavy granular product which is free from dust.

*Washed pyrites.*—It is frequently found convenient to accumulate cupreous pyrites at the mines, and wash out the copper with water—a process requiring several years to remove the copper—the cupreous liquor being passed through canals over pig-iron to

precipitate the copper. Pyrites thus treated is known as "washed ore," and is in every way suitable for acid manufacture.

*Burning qualities.*—This is one of the most important aspects of pyrites, and one which cannot be gauged from analysis or by any other means than a large-scale test. Some kinds will burn freely, leaving a cinder containing only 2 per cent. or less of sulphur; others of very similar composition are more massive in texture and burn very slowly or with great difficulty.

### *Chemical Considerations.*

A full analysis of pyrites will usually contain eight or ten items, most of which are important; these are as follows:—

*Sulphur.*—Pure iron-pyrites ( $\text{FeS}_2$ ) contains 53·4 per cent. of sulphur. It very seldom contains more than 51 per cent. in large consignments, and the average percentage of sulphur in pyrites imported from Spain and Portugal is probably about 47½ per cent. Free-burning pyrites containing as little as 30 per cent. sulphur may be used in an emergency, as was the case with pyrites from the Cae Coch mine, North Wales, during the war. The extra handling expenses, however, make the value of a unit of sulphur much lower than would otherwise be the case.

*Iron.*—The cinders from fairly pure pyrites are ultimately smelted for iron, and the percentage of this metal is therefore of importance. It is of importance also as indicating the percentage of impurities, but from the chemical standpoint it does not enter directly into the considerations of the acid manufacturer.

*Copper.*—Almost all iron-pyrites contains a small percentage of copper. When this exceeds a certain amount (about 5 per cent.) the mineral is called copper-pyrites, as distinct from cupreous iron-pyrites. When the copper falls short of a certain percentage, usually in the neighbourhood of 0·75 per cent., it cannot be profitably extracted, and the pyrites is described as non-cupreous. Pyrites containing from 1 to 5 per cent. of copper is described as cupreous pyrites, and the copper forms one of the valuable constituents of the ore.

The cinders from cupreous pyrites are always submitted to a process for the extraction of copper, and the one usually employed is the well-known chloridizing and leaching wet copper extraction process.

When an acid manufacturer or chemical manufacturer, other than the mine-owner, purchases the copper content, he pays for it on the basis of the market value of copper, usually "Best Selected" less a certain "returning charge." In addition, a certain proportion of the copper in the ore, say 0·75 per cent. in the crude ore, is allowed him as free copper, and is intended to cover the costs of extraction. In the United Kingdom, however, the copper value of a very large amount of cupreous pyrites is

retained by the mine owners, who treat the cinders at their own works.

The presence of copper is of significance to the acid manufacturer apart from its intrinsic value, as a certain amount of sulphur is retained by the copper which thus diminishes the amount of sulphur available for acid manufacture. Pyrites containing 2 per cent. of copper retains after burning about 1 per cent. of sulphur in combination with the copper.

*Arsenic.*—Almost all pyrites, and especially cupreous pyrites, contains small but important amounts of arsenic, but commercial supplies containing less than about 0.025 to 0.015 per cent. are described as non-arsenical. The general run of Spanish pyrites contains about 0.3 to 0.4 per cent. of arsenic, and the acid manufactured therefrom has a noticeable amount of arsenic impurity. On the other hand, Norwegian pyrites frequently contains less than 0.01 per cent. of arsenic, and sometimes merely traces. The presence of arsenic in sulphuric acid is of little importance in the manufacture of artificial fertilizers, for which the great bulk of acid is used. Nevertheless, in the case of sulphate of ammonia, good “grey sulphate,” which contains no arsenic, fetches a higher price than “yellow sulphate,” which owes its colour to traces of arsenic.

Sulphuric acid used for many other purposes, especially the manufacture of foodstuffs, must be commercially free from arsenic, and for this reason non-arsenical pyrites is of a higher value than the arsenical variety.

*Lead and Zinc.*—These are important to the acid manufacturer from two points of view: firstly, in the same way as copper, they fix a certain amount of sulphur, which is thus rendered unavailable for acid manufacture; and, secondly, the metals themselves are volatile and pass over with the sulphur dioxide fumes, a fact which, in the manufacture of acid by the contact process, is of great importance owing to the detrimental effect on the contact mass.

*Selenium and Tellurium.*—These elements occur in most pyrites to a very small extent, averaging from 0.01 to 0.025 per cent. They are of no importance to the sulphuric acid manufacturer, although, if the selenium is present in comparatively large quantities, it may colour the acid pink. The pink colour, however, which is frequently associated with certain types of sulphuric acid, is usually due to the presence of iron and not to selenium.

*Alumina and Silica.*—These impurities are present in almost all pyrites, and are objectionable, firstly, as being a diluent and causing extra handling; secondly, as lessening the value of the cinders to the ironmaster; and thirdly, as causing detonation.

Some pyrites when put into the furnace explodes with considerable force, injures the furnace, and prevents the regular burning of the mineral. This is probably due to the presence of hydrated silicates of aluminium, and to a large extent may be avoided by a previous thorough drying of the mineral, an item of expenditure which the acid-maker is not willing to incur. For this reason, in contracts for sale of pyrites, it is not unusual to embody a sliding scale of allowances when the percentage of silica exceeds a certain amount, usually 6 to 8 per cent.

*Lime, Magnesia, Baryta, etc.*—These items are generally included with silica under the heading “insolubles.” They are objectionable not only as diluents, but also as fixing their equivalent of sulphur, and they may render the iron cinders valueless.

### WORLD'S PRODUCTION.

The world's production of pyrites in 1913 was about 5½ million tons, of which Spain produced more than half.

Of the chief countries producing pyrites, only seven figure largely among those exporting, namely:—*Canada*, which exported in 1913 about 28 per cent. of her production to the United States; *France*, exporting in 1913 about 30 per cent. of her production; *Italy*, which exported 9 per cent. in 1913; *Norway*, whose exports were slightly in excess of the 1913 production; *Portugal*, whose exports did not differ materially from the production for 1913; *Spain*, the main source of the world's supply, which exported over 2·8 million tons and produced over 3·1 million tons in all, and *Sweden*, whose exports were about 1½ per cent. of her 1913 production.

The other producing countries consumed practically the whole of the pyrites mined within their own borders. France, which figures among the exporting countries, needs pyrites greatly in excess of her production, and the fact that she exported pyrites must not therefore be taken as an indication that she is self-supporting. On the contrary, in 1913 she imported 572,406 tons. This anomaly is explained by the fact that the principal French mines are in the south, whereas many of the principal consumers are on the Atlantic seaboard and the Channel coast. Pyrites can be conveyed much more cheaply by sea than by rail, hence the consumers in the north and west find it more economical to purchase their pyrites from abroad, while the French pyrites mining companies export their surplus production to adjoining countries, especially Switzerland.

Although the war interfered very considerably with the production of various countries, individually considered, it did not, on the whole, bring about any material reduction in the total production. Pyrites is a mineral even more essential to war than to peace conditions, for it is at the base of all explosives requirements.

A comparison of the effects of the war on the production of the principal countries is interesting and instructive.

Canada, by 1917, had increased her pre-war output from 141,577 tons to 372,008 tons, and although her own consumption increased to a limited extent, the cause of the impetus given to pyrites mining was mainly the war demand in the United States.

In France, as might be expected, production fell in 1914 and 1915, improving afterwards, until in 1917 it was only 30,000 tons less than in 1913.

Germany, cut off from external supplies, increased her domestic output from 197,656 tons in 1914 to 804,738 tons in 1918, her 1913 figure being 224,737 tons.

Italy, despite the drain on her male population, recorded a noteworthy increase in pyrites production as the war proceeded, attaining nearly 500,000 tons in 1917 as compared with 312,234 tons in 1913.

The Scandinavian countries, Sweden and Norway, show diverse results. Sweden quadrupled her production from 1913 to 1918, although a relatively unimportant producer in the pre-war period. Norway, on the other hand, had been an important exporting country, and in 1915 her production was 16 per cent. above 1913. In the following year there was, however, a remarkable fall, and 1917 shows only an 11 per cent. increase on 1916.

The production of Spain remained fairly constant during the war, but 1918 shows a marked falling off, which was continued during 1919 and was principally due to labour troubles.

With the cessation of hostilities, the tendency is for many countries to revert to their pre-war basis of production. Nor is it difficult to understand that such reversion is almost inevitable. Pyrites is a low-priced mineral depending on the relatively cheaper ocean transport, and the demand must therefore centre, in the main, upon those countries possessing deposits located close to the sea. Spain and Norway owe their pre-eminence as exporting countries to the proximity of their pyrites deposits to the coast.

*World's Production of Pyrites\**  
(long tons).

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom...	11,427	11,654	10,535	10,481	8,515	22,195	7,336
Union of South Africa	—	—	487	4,711	3,846	4,375	5,007
Canada ... ..	141,577	203,852	255,391	276,117	372,008	367,514	157,578
Newfoundland	—	1,335	4,139	—	—	—	—
(exports)†							
Australia ... ..	10,216	9,759	19,394	18,414	11,261	7,358	7,593
Belgium ... ..	264	107	127	209	80	6	59
Bosnia and Herzegovina	7,577	4,387	—	9,108	2,759	—	—
France ... ..	306,166	196,123	193,446	215,845	276,284	256,126	116,795
Germany (Prussia)	224,737	197,656	420,015	616,710	754,054	804,738	342,983
Greece ... ..	126,796	126,982	11,918	19,557	—	12,246	2,316
Hungary ... ..	104,915	100,725	107,086	—	170,264	—	98,000
Italy ... ..	312,234	330,139	363,384	403,696	492,734	474,313	366,586
Norway ... ..	434,199	408,218	505,085	290,607	323,411	333,403	—
Portugal ... ..	428,929	309,238	232,942	233,127	184,762	110,079	90,522
Spain ... ..	3,119,016	2,421,032	2,159,643	2,658,989	2,749,841	1,558,992	1,020,202
Sweden ... ..	33,767	32,778	75,097	96,275	140,368	138,912	107,022
Algeria ... ..	—	108	118	443	1,162	5,491	—
United States ...	341,338	336,662	394,124	439,132	482,662	464,494	420,647
Peru ... ..	—	—	—	49	149	—	—
Japan ... ..	112,803	113,984	66,492	89,609	119,489	104,120	125,033

*Exports of Pyrites from Chief Producing Countries*  
(long tons).

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Canada ... ..	41,130	80,356	122,855	139,930	249,684	214,639	79,544
France ... ..	92,327	56,848	18,646	16,410	6,881	11,344	9,509
Italy ... ..	28,336	72,693	53,526	143,444	167,565	191,205	69,546
Norway—							
Cupreous pyrites	419,032	354,439	459,258	249,290	209,487	236,904	116,682
Calced pyrites (purple ore).	34,472	42,335	45,695	46,759	40,702	28,647	40,566
Spain ... ..	2,856,890	2,512,755	2,226,850	2,700,655	1,933,358	1,053,994	599,353
Sweden ... ..	492	3,389	89,355	13,778	29,321	37,976	—

*Imports of Pyrites into Chief Countries of Consumption*  
(long tons).

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom...	781,711	803,149	903,467	949,996	854,241	836,703	344,457
Union of South Africa.	20,450	3,491	12,518	22,967	16,487	6,810	6,164
Australia ‡ ...	12,335	—	24,068	2,870	1,500	—	—
France ... ..	572,406	594,938	417,979	779,613	483,719	316,118	94,814
Italy ... ..	39,861	26,816	23,776	2	—	21	—
Sweden ... ..	138,739	147,960	156,654	125,948	102,224	107,824	70,559
United States ...	850,592	1,026,617	964,634	1,244,662	967,340	498,786	388,973

\* In addition to the countries mentioned in this table, Bosnia, Finland, Russia, Serbia, Armenia and Cuba also produce pyrites. The average annual pre-war production of the Bakovisti mines in Bosnia was about 5,000 tons. In 1913 the production of Russia was 56,400 tons; during the first six months of 1920 it was 11,000 tons. The United States imported from Cuba 2,200 tons in 1914 and 23,237 tons in 1919. Statistics of other countries are not available.

† Fiscal years ending June 30.

‡ 1913 calendar year; 1915 onward, fiscal years ending June 30. Figures for 1914 not available.

## BRITISH EMPIRE.

**United Kingdom.\***

The United Kingdom is dependent upon imports for its supply of pyrites. There is a small domestic production, which is obtained chiefly as a by-product during coal-mining operations in Warwickshire, Northumberland, Derbyshire, Staffordshire, Shropshire, and in smaller quantities from Cumberland, Nottinghamshire and Glamorganshire. In these coalfields the mineral occurs in layers and nodules interbedded in the coal seams, and it is recovered during the process of preparing the coal for market. Small quantities of pyrites are obtained also from County Wicklow and other places in Ireland.

During the war an effort was made to increase the domestic production. The Cae Coch mine, situated four miles north of Llanrwst, in Carnarvonshire, was re-opened and some thousands of tons of low-grade pyrites were obtained from it, but the mine was closed before the end of the war, partly through increasing facilities for importing superior grades, and partly because the Carnarvonshire pyrites was unsuitable for peace-time requirements.

The greater part of the pyrites used by acid manufacturers in the United Kingdom is cupreous and is imported largely from Spain, Portugal and Norway. The exports of pyrites from the United Kingdom are not important, and they are confined to occasional re-exports of foreign material. The only exports recorded during the period under review were 1,293 tons shipped to British Possessions in the year 1914, and 1,595 tons exported to foreign countries in the following year. Early in the war, increasing quantities were required to meet the great demand for sulphuric acid for the manufacture of high explosives and other munitions. Arrangements were made whereby the British and Allied Governments were able to secure the whole of the shipments of Norwegian pyrites, and ample supplies were obtainable in Spain and Portugal, but great difficulties were experienced in providing cargo space. In order to relieve the situation, efforts were made to substitute waste nitre-cake for sulphuric acid in many trade processes the products of which were, equally with explosives, necessary for carrying on the war. These efforts met with considerable success, the monthly consumption of nitre-cake rising to the substantial figure of 26,000 tons, equivalent to a saving of 6,000 tons of pyrites.

From the commencement of the war until the end of December, 1917, the Government left British consumers of pyrites, with the exception of those who required the mineral for the manufacture of explosives, to make their own arrangements for purchase and importation. At a very early stage of the war the

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\* Journ. Soc. Chem. Ind., 1920, **39**, No. 23, 407. Mines and Quarries, General Report with Statistics, Part III, by the Chief Inspector of Mines (Annual). Annual Statements of the Trade of the United Kingdom.

Government acquired a large stock of pyrites which was primarily used to meet the needs of the Government explosive factories, but a considerable portion was diverted to commercial consumers.

On and from the 1st January, 1918, the Government took over the control and became responsible for the purchase and shipment of all the pyrites required throughout the United Kingdom. This course became necessary owing to the increasing difficulty of securing adequate shipping space for imports, which resulted in a rapid increase in the freight rates. Under Government control the sulphur content of pyrites was sold to consumers at a flat rate, delivered to consumers' works, and consequently it became possible and necessary to fix the price of sulphuric acid.

On the signing of the Armistice, pyrites was very speedily freed from control, and within six months consumers reverted to the normal pre-war practice of arranging for their own supplies.

*Production of Pyrites in the United Kingdom.*

Year	Quantity (long tons).	Value (£).
1913	11,427	5,988
1914	11,654	4,759
1915	10,535	4,873
1916	10,481	6,875
1917	8,515	8,145
1918	22,195	20,398
1919	7,336	7,807

*Imports of Pyrites and Cupreous Pyrites into the United Kingdom.*

From	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Newfoundland ...	9,526	8,168	—	—	—	—	—
Other British Possessions.	—	10	—	—	—	—	—
Total from British Possessions.	9,526	8,178	—	—	—	—	—
France ...	30	2,056	9,700	7,422	—	—	3,597
Italy ...	1,500	7,557	—	11,923	600	—	8,064
Norway...	133,925	106,672	78,281	24,639	49,960	112,889	14,929
Portugal ...	75,993	73,219	59,143	83,506	31,096	28,003	15,915
Spain ...	559,910	604,367	751,978	819,465	772,585	695,811	299,662
Other Foreign Countries	827	1,100	4,365	3,041	—	—	2,290
Total from Foreign Countries.	772,185	794,971	903,467	949,996	854,241	836,703	344,457
TOTAL ...	781,711	803,149	903,467	949,996	854,241	836,703	344,457

*Imports of Pyrites and Cupreous Pyrites into the United Kingdom—continued.*

From	Value (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
Newfoundland... ..	18,690	14,260	—	—	—	—	—
Other British Possessions.	—	32	—	—	—	—	—
Total from British Possessions.	18,690	14,292	—	—	—	—	—
France ... ..	45	1,042	11,399	11,228	—	—	4,004
Italy ... ..	3,000	9,407	—	30,031	4,470	—	19,616
Norway ... ..	230,865	168,345	125,244	56,214	159,421	371,719	46,255
Portugal ... ..	103,947	100,446	98,769	228,768	96,795	111,173	40,432
Spain ... ..	1,005,168	1,025,172	1,325,780	1,880,795	2,077,340	2,230,516	876,650
Other Foreign Countries	2,067	1,350	6,592	6,055	—	—	5,496
Total from Foreign Countries.	1,345,092	1,305,822	1,567,784	2,213,091	2,338,026	2,713,408	992,453
TOTAL ...	1,363,782	1,320,114	1,567,784	2,213,091	2,338,026	2,713,408	992,453

**Union of South Africa.\***

South Africa produces important quantities of sulphuric acid. Before the war, acid manufacturers depended almost exclusively upon imported Spanish pyrites for their raw material. During the war, the difficulty experienced in obtaining regular imports led to the utilization of the considerable supplies available in the Transvaal, where auriferous pyrites is obtained as a by-product in gold-mining. In 1919 these mines were supplying about 400 tons of pyrites per month. Advantage was taken also of the large quantities of auriferous pyrites accumulated in the tailing dumps on many of the abandoned gold mines in the Transvaal. This ore when concentrated yields from 40 to 45 per cent. of sulphur. In the Cape Province an important deposit of pyrites was worked during the years 1916 and 1917, in the Areachap district of Gordonia. This deposit has an average width of about 50 feet and has been traced for a distance of about 1,450 feet along the outcrop. The ore from the mines averages 39 to 48 per cent. of sulphur, with only a small percentage of copper and a trace of arsenic, but the lack of railway facilities has greatly hindered the development of this important deposit.

\* The South African Journal of Industries, 1919, 2, No. 2, 125. Producing Sulphur in South Africa, by T. G. Trevor; South African Journal of Industries, 1920, 3, No. 11, 1012. Report of the Government Mining Engineer, South Africa (Annual). Trade and Shipping of the Union of South Africa and of Southern and Northern Rhodesia (Annual).

*Production, Sales and Shipments of Pyrites in South Africa.\**

Year.	Transvaal.			Cape of Good Hope.			Total.		
	Sales and Shipments.		Output.	Sales and Shipments.		Output.	Sales and Shipments.		Output
	Quantity.	Value.	Quantity.	Quantity.	Value.	Quantity.	Quantity.	Value.	Quantity.
	Long tons	£	Long tons	Long tons	£	Long tons	Long tons	£	Long tons
1915	487	939	—	—	—	—	487	939	—
1916	3,931	7,263	—	780	756	—	4,711	8,019	—
1917	2,361	4,251	3,565	189	212	281	2,550	4,463	3,846
1918	4,134	7,002	4,375	—	—	—	4,134	7,002	4,375
1919	4,939	8,894	5,007	—	—	—	4,939	8,894	5,007

**Canada. †**

Most of the Canadian pyrites deposits at present worked are situated within easy reach of the chief United States acid plants, to which about 75 per cent. of the pyrites produced in Canada is exported. During the war United States acid manufacturers were unable to obtain regular supplies of European pyrites, and turned to Canada for the raw material required to meet the increased demand for sulphuric acid due to the war. The Canadian production was greatly stimulated, rising to the record figure of 372,008 tons in the year 1917. In the following year labour troubles, transportation difficulties, and, to some extent, the substitution of crude sulphur for pyrites in many of the United States acid plants, tended to lower output, but the pyrites-mining industry remained prosperous until the demand for sulphuric acid was lessened by the cessation of hostilities. During the year 1919 the total production of pyrites in Canada fell to little more than the pre-war level.

Large deposits of pyrites occur at many localities in Canada, but pyrites-mining is an established industry only in the provinces of Ontario, Quebec and British Columbia.

In Ontario the chief producing district is situated in Hastings county, where massive pyrites occurs as lenticular deposits of great size. The bulk of the ore produced is treated at Sulphide, the remainder being shipped to the United States. Increasing quantities of fine-grained pyrites are being produced from a deposit situated at Northpines, north-western Ontario. The pyrites in this deposit is associated with a little pyrrhotite. It has an average sulphur content of about 45 per cent., and has proved of good quality for acid-making, the residual sulphur lost in the cinder being only about 1 per cent. The deposit has

\* For imports of sulphur rock (including pyrites) into South Africa, see Sulphur section, p. 11.

† Annual Reports of the Mineral Production of Canada. Annual Reports of the Ontario Bureau of Mines. Annual Reports on the Trade of Canada.

a length of about 1,000 feet and averages 45 feet in thickness. The output of this mine is shipped to the United States. At Goudreau, in the northern part of the Michipicoten area, there are extensive deposits of pyrites which are quarried by steam shovels, the product, after grading, being shipped to the United States. The only other locality in Ontario where pyrites was mined on an important scale during the period under review is the Michipicoten mining division, where lenses and pockets of loose granular pyrite associated with hæmatite ore were worked in the Helen Mine. Although mining operations at this mine were suspended in 1918, more than 2,200 tons of pyrites were obtained from the stock-pile during the year 1919.

In the province of Quebec the mineral mined is chiefly cupreous pyrites, containing about 40 per cent. of sulphur and 2.75 per cent. or less of copper, with a little gold and silver. The chief producing mines are the Eustis and Weedon, both of which are situated in the Eastern Townships. The output is shipped chiefly to the New England acid plants.

In 1916 a sulphuric acid plant was erected at Trail, British Columbia, to treat the pyrites which occurs abundantly in the Sullivan Mine, Kimberley, and increasing quantities of pyrites are being obtained from this deposit. There are also large reserves of high-grade pyrites at the Hidden Creek Mines at Anyox, British Columbia. These mines are worked primarily for the copper, gold and silver values in the ore, but there are also present large quantities of high-grade pyrites which are shipped to an acid plant at Barnett.

During 1916, 1917 and 1918 a large amount of diamond-drilling and development work was carried out on the pyrites deposits situated on the Ecstall River, about 35 miles from Port Essington, B.C. Trial shipments from this district have proved the pyrites to be very satisfactory for the manufacture of acid.

*Canadian Production and Exports of Pyrites.*

	Quantity (long tons).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
<i>Production.</i>							
Quebec ... ..	77,959	105,088	127,442	116,642	109,716	111,492	47,095
Ontario ... ..	63,618	98,764	127,949	158,529	257,195	239,738	104,474
British Columbia	—	—	—	946	5,097	16,284	6,009
Total ... ..	141,577	203,852	255,391	276,117	372,008	367,514	157,578
Sulphur content	*	*	103,712	104,442	138,797	137,740	58,637
<i>Exports</i> ... ..	41,130	80,356	122,855	139,930	249,684	214,689	79,544

\* Not stated.

*Canadian Production and Exports of Pyrites—continued.*

	Value* (£).						
	1913.	1914.	1915.	1916.	1917.	1918.	1919.
<i>Production.</i>							
Quebec ... ..	72,761	98,082	118,946	109,015	104,448	105,792	42,338
Ontario ... ..	35,818	57,024	86,302	115,734	225,180	236,242	59,548
British Columbia	—	—	—	1,104	5,947	13,220	7,011
Total ... ..	108,579	155,106	205,248	225,853	335,575	355,254	108,897
<i>Exports</i> ... ..	44,092	78,747	109,858	116,047	202,958	197,722	80,939

**Newfoundland. †**

Pyrites occurs abundantly, associated with copper ores, around Notre Dame Bay, on the north-east coast of Newfoundland. Deposits of high-grade pyrites carrying about 53 per cent. of sulphur with about  $1\frac{1}{2}$  per cent. of copper have been mined at Pilley's Island and Tilt Cove, Notre Dame Bay, the produce being shipped chiefly to the United Kingdom and the United States for the manufacture of sulphuric acid.

Other deposits are known to occur near York Harbour and Middle Arm, both situated on the Bay of Islands; at Port-au-Port Bay, 30 miles north-east of Cape St. George; in the Codroy Valley; and at Rowsell's Harbour, Labrador.

In spite of the numerous occurrences of pyrites in Newfoundland, the output of ore has been small and irregular. The only recorded export during the period under review was 1,335 tons, valued at £2,798, during the year ending June 30, 1914, and 4,139 tons, valued at £3,880, during the year ending June 30, 1915.

**Cyprus.**

The island of Cyprus has been prospected for pyrites during the past few years. An important deposit has been found at Foucassa Hill near Skouriotissa in the district of Nicosia.

The Skouriotissa ore-body has been proved by systematic drilling, and is estimated to contain not less than five million tons of cupreous pyrites of good quality. An average analysis gives 47·5 per cent. sulphur, about 2·5 per cent. copper, 41·85 per cent. iron, and ·01 per cent. arsenic.

The deposit is near the seashore and a mineral railway connecting the mine and the coast has been constructed and equipped. A jetty has been built for loading the ore into barges by which it is to be transferred to vessels standing out in deeper water.

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Newfoundland Customs Returns (Annual).

Indications of other deposits of the same kind are numerous in the south-western and southern parts of the island, but no other large body of high-grade ore has as yet been discovered.

According to the Colonial Report on Cyprus for 1920 (No. 1093), some 2,000 tons of cupreous pyrites were extracted during that year.

### **India.\***

No large deposits of pyrites have yet been discovered in India. Pyritous shale, suited for the manufacture of alum, is found at Dandot and Pidh in the Salt Range, at Madh in Cutch and at Kalabagh and various other places in the Punjab. The average sulphur content of these shales is only 9·5 per cent.

### **Australia.†**

Pyrites is obtained in copper-mining operations at Gormanston, Tasmania, the output being shipped to acid and superphosphate works situated in Victoria and Western Australia. Small quantities of pyrites are also mined in the Comstock district.

The production of pyrites in Tasmania has declined steadily since the year 1916, only 3,457 tons being produced in the year 1919.

Copper-bearing pyrites is mined at the Eulamina and Murrin Murrin mines in the Mount Margaret goldfield, Western Australia. Production from these fields has steadily declined since the year 1913, when the annual output of pyrites exceeded 10,200 tons, and it amounted to only 2,252 tons in the year 1918. Latterly there has been some recovery, but the total quantity mined is still small.

A small amount of pyrites is mined in the western part of New South Wales.

The sulphur dioxide given off in the roasting of lead-zinc ores, together with all the pyrites produced in Australia, falls short of meeting Australia's needs in connection with the manufacture of sulphuric acid required for the production of superphosphate. For this purpose a considerable quantity of pyrites is imported, and it would be very useful if some deposit of sulphur or pyrites could be found, sufficiently large, and suitably situated in relation to industrial centres, to supply Australia's needs.

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\* Records Geol. Surv. India, vol. LII, pp. 250-251 [1921].

† Reports of the Secretary of Mines, Tasmania (Annual). Reports of the Department of Mines, Western Australia (Annual). Trade and Customs and Excise Revenue of the Commonwealth of Australia (Annual).

*Production of Pyrites in Australia.*

Year.	Western Australia.		Tasmania.		Total.	
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value (£).	Quantity (long tons).	Value (£).
1913 ... ..	10,216	3,658	—	—	10,216	3,658
1914 ... ..	9,759	3,485	—	—	9,759	3,485
1915 ... ..	6,558	2,368	12,836	8,945	19,394	11,313
1916 ... ..	4,409	2,263	14,005	13,597	18,414	15,860
1917 ... ..	3,575	1,752	7,686	7,137	11,261	8,889
1918 ... ..	2,252	1,629	5,106	4,667	7,358	6,296
1919 ... ..	4,136	4,919	3,457	4,288	7,593	9,207

*Imports of Pyrites into Australia.*

From	Quantity (long tons).					
	Calendar Year 1913.	Fiscal Years ending June 30.				
		1915.	1916.	1917.	1918.	1919.
New Zealand ... ..	—	446	—	—	—	—
Portugal ... ..	—	—	—	1,500	—	—
Spain ... ..	12,835	23,622	2,870	—	—	—
Total ... ..	12,835	24,068	2,870	1,500	—	—
	Value (£).					
		1915.	1916.	1917.	1918.	1919.
New Zealand ... ..	—	4,898	—	—	—	—
Portugal ... ..	—	—	—	4,208	—	—
Spain ... ..	28,255	47,018	6,393	—	—	—
Total ... ..	28,255	51,916	6,393	4,208	—	—

**New Zealand.†**

Pyrites occurs in large granular masses in the rhyolite and rhyolitic tuffs at Rotorua and Rotomahana, in the North Island of New Zealand, and it is a common constituent of many of the gold-bearing reefs in the Thames and Coromandel districts of that island and in the Reefton district of the South Island. Very little pyrites was mined during the period under review, the only recorded outputs being 4 tons in the year 1916 and 1 ton in 1918, both parcels being exported.

**FOREIGN COUNTRIES.****Austria.‡**

During the war the Austrian production of pyrites declined. In 1919 the output was 9,148 tons, obtained from four mines, the Panzendorf-Tessenberg mine in the Hall district of the Tyrol

\* Represents the value of sulphur only.

† New Zealand Mines Statements (Annual).

‡ Mitteilungen über den österreichischen Bergbau, 1920.

being the chief producer. There was also a small production of cupreous pyrites from the Grossfragant mine in the canton of Klagenfurt from which an output of 310 tons was obtained.

### Belgium.\*

There are no deposits of pyrites of any great importance in Belgium. The small annual output shown in the following table is probably obtained as a by-product during coal-mining operations.

#### *Production of Pyrites in Belgium.*

Year.	Quantity (long tons).	Value† (£).
1913 ... ..	264	88
1914 ... ..	107	44
1915 ... ..	127	56
1916 ... ..	209	92
1917 ... ..	80	36
1918 ... ..	6	4
1919 ... ..	59	264

### France.‡

France is an important producer of iron-pyrites. The deposits worked are situated at Sain Bel in the Rhône department, about 15 miles north-west of Lyons. The ore occurs chiefly in lenticular masses, which in places attain a thickness of more than 65 feet. The pyrites mined is very pure, averaging about 48 per cent. of sulphur with practically no copper or other associated minerals.

In the year 1913 France consumed 786,245 tons of pyrites, of which total about 39 per cent. was obtained from domestic mines, the balance being imported chiefly from Spain and Portugal.

#### *French Production, Imports and Exports of Pyrites.*

Year.	Pro- duction.	Sulphur content.	Imports.		Exports.	
	Quantity (long tons).	Quantity (long tons).	Quantity (long tons).	Value \$ (£).	Quantity (long tons).	Value \$ (£).
1913 ...	306,166		572,406	626,120	92,327	112,600
1914 ...	196,123	93,809	594,938	725,600	56,848	69,320
1915 ...	193,446	92,738	417,979	679,680	18,646	30,320
1916 ...	215,845	101,876	779,613	1,743,160	16,410	36,680
1917 ...	276,284	132,265	483,719	1,769,840	6,881	25,160
1918 ...	256,126	122,395	316,118	1,153,000	11,344	41,520
1919 ...	116,795		94,814	346,920	9,509	34,800

\* Statistique des Industries Extractives et Métallurgiques (Annual).

† Values converted to £ sterling at the rate of 25 francs = £1.

‡ Statistique de L'industrie Minérale en France et en Algérie (1914-1918).  
Le Commerce de la France (Annual).

§ Values converted to £ sterling at the rate of 25 francs = £1.

## Germany.

The larger part of the pyrites mined in Germany is obtained from an important deposit situated at Meggen, in Westphalia. The ore-body consists essentially of high-grade pyrites associated with barytes and a little galena, zinc-blende and chalcopyrite. Silver is occasionally present in small quantities. The deposit has a thickness of about 13 feet, and has been followed for a distance of about  $1\frac{1}{2}$  mile along the strike. During the war the output of pyrites from this district was greatly increased, about 80,000 tons of ore being produced monthly from the mines shortly before the cessation of hostilities.

The Rammelsberg deposit, which is situated on the northern slope of the Harz Mountains, near the town of Goslar, has long been a large producer of pyrites. The chief minerals of this deposit are zinc-blende, chalcopyrite, galena, iron-pyrites and arsenopyrite, which occur abundantly in a gangue of barytes. The thickness of the deposit varies from a few feet up to 90 feet, and it has a length of more than 6,000 feet.

An important quantity of iron-pyrites is also produced as a by-product during lead-, zinc-, and copper-mining operations in Silesia and other provinces.

Before the war Germany imported annually about 1,000,000 tons of pyrites, the greater part of which was obtained from Spain and Portugal. During the early years of the war period Germany was able to obtain supplies from Norway, Greece, and Turkey, but in 1915 the Norwegian Government placed an embargo on the export of pyrites to Germany, and when, subsequently, Greece joined the Allies, further supplies from that source were unobtainable. The shortage was met chiefly by increased production from the domestic and Polish deposits, and by considerable importation of Swedish pyrites.

### *Production of Pyrites in Germany.*

Year.				Prussia.		Bavaria.*	
				Quantity (long tons).	Value † (£).	Quantity. (long tons).	Value † (£).
1913	...	...	...	224,737	115,442		
1914	...	...	...	197,656	106,749	4,927	3,094
1915	...	...	...	420,015	319,096	367	135
1916	...	...	...	616,710	566,567	299	350
1917	...	...	...	754,054	623,056	4,348	3,414
1918	...	...	...	804,738	827,799	9,591	11,670
1919	...	...	...	342,983	718,587	7,277	10,800

\* Pyrites and other sulphur minerals.

† Values converted to £ sterling at the rate of 20 marks = £1.

**Greece.\***

Before the war Greece was an important producer of pyrites, but during the war period the output decreased and only 12,246 tons were raised in 1918. The most productive mines are situated near Hermíone, in Argolis, where the pyrites mined carries about 46 per cent. of sulphur. Other important deposits are situated between Polygyros and Molivoporgos at the head of the Cassandra Gulf; on Cassandra Mountain, and at various places in the Madenochoria area in Chalkidike.

*Production and Sales of Pyrites in Greece.*

Year.	Production.		Sales.	
	Quantity (long tons).	Quantity (long tons).	Value† (£).	
1913	...	126,796	159,655	106,107
1914	...	126,982	130,450	87,749
1915	...	11,918	19,003	13,759
1916	...	19,557	11,311	9,760
1917	...	—	10,301	6,927
1918	...	12,246	12,405	10,086
1919	...	2,316	2,270	3,230

**Hungary.**

Prior to the war Hungary was an important producer of pyrites. The chief producing areas are situated near the town of Leutschau, in the county of Zips. In this district the pyrites occurs in lenticular bodies of great size, associated with a small amount of chalcoppyrite. These deposits have a thickness varying from 50 feet up to 130 feet, and have been followed along the strike for about 2,000 feet. The sulphur content of the pyrites averages about 47 per cent.

Extensive deposits of pyrites usually containing some chalcoppyrite were worked during the period under review in the Sinjaka and Jazero districts of Bosnia. These districts are now included within the boundaries of Jugoslavia.

*Production of Pyrites in Hungary.*

Year.	Quantity (long tons).			
1913	...	...	...	104,915
1914	...	...	...	100,725
1915	...	...	...	107,036
1916	...	...	...	—
1917	...	...	...	170,264
1918	...	...	...	—
1919	...	...	...	98,000‡

\* Handbook of Macedonia and surrounding Territories, London, 1920, p. 380.  
Tableaux Statistiques du Mouvement Minier de la Grèce (Annual).

† Values converted to £ sterling at the rate of 25 francs = 1£.

‡ Estimated.

**Italy.\***

The Italian production of iron-pyrites increased rapidly during the war, the total output rising to 492,734 tons in the year 1917. With the cessation of hostilities the output dropped to about 17 per cent. above the pre-war level. A part of the mineral produced is copper-bearing, but very pure pyrites is extensively mined at Gavorrano, Ravi and Giglio, in the province of Grosseto. The Gavorrano pyrites is particularly well suited for the manufacture of sulphuric acid, as its sulphur content averages 48·8 per cent. and it is practically free from arsenic. Important quantities of pyrites are obtained from the province of Torino, where the chief mines are the Brosso and Traversella. Smaller quantities are obtained from the provinces of Genoa and Vicenza. The larger part of the Italian output of pyrites is treated for the manufacture of sulphuric acid in Tuscany, Liguria, Piedmont and Venetia.

*Production of Pyrites in Italy.*

Year.	Iron-pyrites.		Cupreous Iron-pyrites.		Total.	
	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).
1913 ...	287,383	246,632	24,851	18,316	312,234	264,948
1914 ...	294,353	287,171	35,786	26,187	330,139	313,358
1915 ...	322,440	360,208	40,944	38,284	363,384	398,492
1916 ...	384,179	537,292	19,517	23,793	403,696	561,085
1917 ...	478,328	937,826	14,406	27,595	492,734	965,421
1918 ...	474,313	1,135,564	—	—	474,313	1,135,564
1919 ...	—	—	—	—	366,586	1,065,087‡

*Imports and Exports of Pyrites into and from Italy.*

Year.	Imports.§		Exports.	
	Quantity. (long tons)	Value.¶ (£)	Quantity. (long tons.)	Value.¶ (£)
1913 ...	39,861	35,651	28,836	23,446
1914 ...	26,816	23,984	72,693	73,880
1915 ...	23,776	21,265	53,526	54,400
1916 ...	2	3	143,444	192,439
1917 ...	—	—	167,565	340,604
1918 ...	21	76	191,205	699,581
1919 ...	—	—	69,546	254,455

\* Zeitschrift für praktische Geologie, June, 1920, pp. 85-93. Rivista del Servizio Minerario (Annual). Statistica del Comercio Speciale di Importazione di Esportazione.

† Values converted to £ sterling at the rate of 25 lire = £1.

‡ Value of 366,488 tons only.

§ Chiefly from Spain.

|| Chiefly to France.

¶ Values converted to £ sterling at the rate of 25 lire = £1.

### Norway.\*

During the war there was a strong demand for Norwegian pyrites, especially by Sweden, where the supply of Spanish pyrites was considerably curtailed by lack of shipping facilities. The greater demand led to increased production, many new deposits being opened up, while mining operations on the old-established mines were considerably extended.

The Norwegian pyrites deposits are as a rule lenticular in form, the lenses varying from a few feet up to 60 feet in thickness. The pyrites sometimes contains varying quantities of copper. The most important deposits are situated at Snlitjelma near Salten, in Nordland, where the ores mined are concentrated into two products, one of which, containing 4 to 8 per cent. of copper, is smelted locally; the other, containing 1 to 4 per cent. of copper, 45 per cent. of sulphur, 34 to 36 per cent. of iron with about 2 per cent. of silica and alumina, is exported.

Other old-established pyrites mines worked during the period under review, and their output in 1913, were the Lökken, near Meldal, 130,000 tons; Foldal on a tributary of the Glommen river, 65,000 tons; Röstvangen on the Tinoset river, 27,000 tons; Killingdal in Guldal, 24,400 tons; and several mines near Mö in Ranen, and Rörös in Guldal.

The new projects include mines near Ballangen on Ofotenfjord, at Folsteid in Vaagö in the Lofotens, and the Grong mines north-east of Namsos. In 1913, a French company was established to work the Grong pyrites deposits at Skörovas, near Tunnsjön; Gjersvik, on Limingen; Joma, near Huddingsvand; and other occurrences in the neighbourhood of Namsos. It is estimated that there are about 8½ million tons of high-grade ore in these deposits, and that the Grong mines are capable of producing annually 200,000 tons of pyrites containing from 42 to 45 per cent. of sulphur with a little over 2 per cent. of copper. In the year 1918 the Norwegian Government bought these mines, but as yet there has been no production.

#### *Norwegian Production and Exports of Pyrites.*

Year.	Production of Pyrites.		Exports.			
			Pyrites.‡		Calcined Pyrites (Purple Ore).	
	Quantity (long tons).	Value§ (£).	Quantity (long tons).	Value§ (£).	Quantity (long tons).	Value§ (£).
1913	434,199	503,763	419,032	549,516	34,472	45,581
1914	408,218	510,484	354,439	464,812	42,335	53,204
1915	505,085	966,129	459,258	1,254,731	45,695	134,828
1916	290,607	776,882	249,290	953,511	46,759	189,070
1917	323,411	1,110,484	209,487	744,038	40,702	222,403
1918	333,403	1,080,968	236,904	970,860	28,647	194,102
1919			116,682	337,183	40,566	310,328

\* Norges Offisielle Statistikk; Norges Handel (Annual), and Norges Bergverksdrift (Annual). Handbook of Norway and Sweden, 1920.

‡ Cupreous in part.

§ Values converted to £ sterling at the rate of 18·6 Kr. = £1.

### Portugal.\*

The chief deposits of pyrites in Portugal are situated on an extension of the Spanish pyrites belt which extends into Portugal as far as Aljustrel in Alemtejo. The chief producing mines are the Minas de San Domingo operated by English interests, and San João do Deserto owned by a Belgian company. In addition, copper-bearing pyrites is mined at Barrancos and at Serra de Caviara. Small quantities of gold and silver are obtained in the latter mine as a by-product.

The San Domingo deposit is the most important pyrites mine in Portugal. The mineral occurs as lenticular masses in a mineralized zone 2,000 feet in length by about 200 feet in thickness. As mined, the pyrites averages about 0·91 per cent. of copper and 48·28 per cent. of sulphur. The Minas de San João do Deserto is situated about 18 miles south-west of Beira. The pyrites carries about 1 per cent. of copper. In 1915 the mine was closed down owing to high costs of production and war conditions generally.

#### *Portuguese production and exports of Pyrites (chiefly cupreous).†*

Year.			Production (long tons).	Exports‡ (long tons).
1913	...	...	428,929	413,208
1914	...	...	309,238	307,616
1915	...	...	232,942	218,118
1916	...	...	233,127	227,176
1917	...	...	184,762	68,529
1918	...	...	110,079	60,490
1919	...	...	90,522	66,827

### Russia.§

Pyrites is widely distributed in all the chief mining districts in Russia, but production has been greatly hindered by the lack of adequate transport facilities from the mines and the small domestic demand.

In Central Russia pyrites occurs in all the principal coalfields, but the mineral is usually picked out during the process of preparing the coal for market and is wasted on the dumps. It has been calculated that more than 2,000 tons of pyrites carrying about 30 per cent. of sulphur is wasted in this way annually.

The most important pyrites deposits in Russia occur along the eastern slope of the Ural Mountains. In this region the largest mines are the Spaso, in the Goroblagodat district, which before the war produced about 14,480 tons annually, and the Kalatinsk mine, situated about 8 miles from Neviansk station on the Perm Railway, which is equipped for the production of about 30,000

\* Boletim de Minas (Annual).

† From information furnished by Sir Charles Fielding.

‡ These figures are exports from the chief producing mines only.

§ The Russian Year Book, 1914. The Mineral Resources of Georgia and Caucasia, by D. Ghambashidze; London, 1919.

tons carrying from 41 to 48 per cent. of sulphur. The recently discovered deposit at the Byeloretschensk mine, situated 6 miles from the station of Roudyanka, is likely to prove one of the most important deposits in the Urals. The mine is equipped for an annual production of about 7,000 tons carrying 51 per cent. of sulphur, but this quantity can easily be increased. Before the war about half the output from this property was treated at the sulphuric acid works situated near Roudyanka. In the Kyshtim district several deposits were being worked before the war, notably the Tyzov, and the Annensk about 4 miles north of Tyzov. South of the Kyshtim district the pyrites deposit of Miask is not now being exploited.

In Southern Russia there are many extensive deposits of pyrites. The chief mines worked are at Tanzout, about 6 miles from the station of Karaklis on the Tiflis-Kars Railway. At this locality the deposit, which has a serpentine matrix, is more than 240 feet in thickness and has a length of about 1,500 feet. The pyrites contains from 39 to 40 per cent. of sulphur, and this percentage can be increased to an average of 45 per cent. by hand-picking. The deposit is exposed within 15 feet of the surface, and opencast operations are practicable. The small quantity of pyrites at present produced is shipped to Baku for treatment. Another important deposit in the Caucasus is worked at the Djiraki-dsor mine situated near the village of Tchaikent. Mining is carried on by opencast methods or by means of adits driven into the hillside. The pyrites obtained is very pure, averaging about 51 per cent. of sulphur. The output from the mine is treated at sulphuric acid works in Baku.

Pyrites associated with bituminous shale occurs abundantly in beds up to 7 feet in thickness at several localities near Kutais, the sulphur content amounting to about 50 per cent. Large quantities of pyrites occur in many of the copper mines of the Caucasus. Pyrites is separated from the copper concentrates at the Alaverdi, Kedabeg, Tchorokh river and other copper-concentration plants.

Small quantities of pyrites are mined at Tipasjarvi and Otravaara, in Finland, but the total production from these sources is unimportant.

### **Serbia.\***

The larger part of the Serbian output of pyrites is obtained from the Maidanpek mines in the north-eastern part of the country. During the war these were extensively worked by the Austrians, but they are now leased to a Belgian company.

In Serbian Macedonia there are extensive deposits of pyrites associated with copper ores in the neighbourhood of Trepatsa, but these have not been worked for many years.

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\* Foreign Office Handbook, No. 20, Serbia.

**Spain.\***

The pyrites deposits in Spain occupy a belt extending from Aznalcollar, in Sevilla, through Huelva to the Portuguese border. They occur in lenticular masses of variable dimensions, the great majority having a length of about 900 to 2,250 feet, with a thickness ranging from about 50 to 500 feet. The San Dionisio lode of Rio Tinto is exceptional, having a length of  $4\frac{1}{2}$  miles and an extreme thickness of about 800 feet. With the exception of the San Dionisio lode, few of the deposits have a greater depth than about 1,000 feet. The pyrites contains from 2 to 4 per cent. of copper in the upper portions of the lode. With increasing depth the copper values decrease, until at about 325 feet below the outcrop the average copper content is less than 3 per cent. Below this level the ore becomes a pyrites body carrying from 0.5 to 2 per cent. of copper and 44 to 52 per cent. of sulphur. The higher-grade copper ore is smelted locally. The lower-grade copper ore is shipped chiefly to European countries for the recovery of its copper, iron, and sulphur content, and the pyrites ore is treated locally for its copper content, the residue known as "washed ore" being exported for sulphuric acid manufacture.

The pyrites mines of Spain were formerly worked for copper alone, and it was then the custom of mining companies to fire the pyrites in heaps at the mine, in order to burn off the sulphur. This had such injurious effects on the crops of the surrounding country that it was prohibited by the Spanish Government, and the copper was therefore extracted by the process of washing, in the course of which only a comparatively small proportion of the sulphur was removed as sulphate. Owing to the efforts of Englishmen interested in the industry, pyrites was gradually substituted for Sicilian sulphur in the manufacture of sulphuric acid, and from that time on the mining of Spanish pyrites developed rapidly.

For many years past it has been the practice to dispose cupreous pyrites in heaps at the mines, and wash it in order to recover the copper. A stock of many million tons of washed pyrites has thus been accumulated, from which the mining companies can draw supplies for export.

*Spanish Production and Exports of Pyrites.*

Year.	Production.			Exports (long tons).
	Cupreous Pyrites (long tons).	Iron-pyrites (long tons).	Total (long tons).	
1913 ... ..	2,207,000†	912,016	3,119,016	2,856,890
1914 ... ..	1,451,976	969,056	2,421,032	2,512,755
1915 ... ..	1,440,816	718,827	2,159,643	2,226,850
1916 ... ..	1,720,637	938,352	2,658,989	2,700,655
1917 ... ..	1,788,624	961,217	2,749,841	1,933,357
1918 ... ..	978,466	580,526	1,558,992	1,053,994
1919 ... ..	595,943	424,259	1,020,202	599,353

\* Estadística Minera de España (Annual). Estadística General del Comercio Exterior de España (Annual).  
† Estimated.

**Sweden.\***

Pyrites is mined in several districts in Sweden, but the chief producing mine is still the Falun in Kopparbergslän. Formerly, this mine was worked for the copper, gold and silver values in the ore, but since 1894 only pyrites has been mined. During the war the production of pyrites in Sweden increased substantially, the output rising from 33,767 tons in 1913 to about 140,000 tons in 1917 and 1918. Several new deposits of pyrites and cupreous pyrites were opened up, notably the Vittensten deposit in Vestre Värmland and the Kvittensten in Värmland.

*Swedish Production, Imports and Exports of Pyrites.*

Year.	Production.		Imports.		Exports.	
	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).
1913 ...	33,767	19,507	138,739	193,688	492	687
1914 ...	32,778	43,434	147,960	143,431	3,389	4,991
1915 ...	75,097	55,228	156,654	164,924	39,355	44,494
1916 ...	96,275	143,813	125,948	357,026	13,778	17,324
1917 ...	140,368	368,219	102,224	468,832	29,321	71,276
1918 ...	138,912	513,748	107,824	579,043	37,976	206,287
1919 ...	107,022	332,567	70,559	366,087	—	—

**Algeria.‡**

There is a small but increasing production of pyrites in Algeria. The larger part of the output is obtained from the department of Constantine.

*Production of Pyrites and Native Sulphur in Algeria.*

Year.	Quantity (long tons).				
1913 ...	...	...	...	...	...
1914 ...	...	...	...	...	108
1915 ...	...	...	...	...	118
1916 ...	...	...	...	...	443
1917 ...	...	...	...	...	1,162
1918 ...	...	...	...	...	5,491
1919 ...	...	...	...	...	...

\* Sveriges Officiella Statistik. Bergshantering Berättelse av Kommerskollegium; Handel Berättelse av Kommerskollegium (Annual).

† Values converted to £ sterling at the rate of 18·2 kronor = £1.

‡ Statistique de l'Industrie Minérale en France et en Algérie (1914-1918).

### United States.\*

In 1913 about 28·6 per cent. of the pyrites consumed in the United States was obtained from domestic sources, the remainder being imported chiefly from Spain, Canada and Portugal. As a rule, the imported pyrites contains about 0·7 per cent. of copper, but large quantities of copper-pyrites carrying as much as 1·25 per cent. of copper are imported from Spain and used in many of the acid plants. This ore is known as "leached" or "washed" ore, having been stacked and allowed to weather, the copper sulphide becoming oxidized to copper sulphate, which can be recovered by washing. Cupreous pyrites carrying an even higher percentage of copper is used in some plants. This ore, after passing through the burners, is treated for the recovery of the copper content.

The domestic production of pyrites is obtained chiefly from the States of Virginia, California, New York, Georgia, Alabama and Missouri. It is obtained also as a by-product of coal-mining in the States of Illinois, Indiana and Ohio, and considerable quantities are produced in Wisconsin during the mining and concentration of zinc ores.

During the war the demand for sulphuric acid stimulated the domestic production of pyrites, but the bulk of the pyrites consumed by the sulphuric acid plants was still imported. Shipments of Spanish pyrites towards the end of the war were strictly limited, but ample supplies of sulphur were available, as well as some lump ore from Canada. Only in the acid plants situated in the middle west, to which transportation charges were high, was there any difficulty in obtaining supplies of pyrites. In these districts many sulphuric acid manufacturers fitted their plants to burn crude sulphur, and this still further tended to reduce the demand for the domestic product.

#### *Production and Imports of Pyrites in the United States.*

Year.	Production.		Imports.	
	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).
1913 ... ..	341,338	267,934	850,592	752,320
1914 ... ..	336,662	267,364	1,026,617	999,443
1915 ... ..	394,124	348,944	964,634	1,003,745
1916 ... ..	439,132	424,584	1,244,662	1,401,733
1917 ... ..	482,662	540,216	967,340	1,246,137
1918 ... ..	464,494	550,941	496,792	571,182
1919 ... ..	420,647	532,952	388,973	453,451

\* U.S. Geol. Surv. Mineral Resources (Annual). Foreign Commerce and Navigation of the U.S (Annual).

† Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

*Imports of Pyrites into the United States.*  
(Fiscal years ending June 30).

From	Quantity (long tons).					
	1914.	1915.	1916.	1917.	1918.	1919.†
United Kingdom ...	16	—	—	—	1,959	—
Canada ...	79,141	99,738	120,896	171,268	205,163	84,761
Newfoundland and Labrador.	1,335	—	—	—	3,670	—
<b>Total from British Possessions.</b>	<b>80,492</b>	<b>99,738</b>	<b>120,896</b>	<b>171,268</b>	<b>210,792</b>	<b>84,761</b>
Germany ...	1,200	—	—	—	—	—
Portugal ...	102,150	57,109	46,351	16,475	2,700	—
Spain ...	638,711	687,812	1,207,323	747,866	596,583	280,725
Cuba ...	2,200	—	—	—	—	23,237
Brazil ...	7,381	—	—	—	—	—
Japan ...	—	—	471	—	—	—
Other Countries ...	—	—	—	—	—	250
<b>Total from Foreign Countries.</b>	<b>751,642</b>	<b>744,921</b>	<b>1,254,145</b>	<b>764,341</b>	<b>599,283</b>	<b>304,212</b>
<b>TOTAL ...</b>	<b>832,134</b>	<b>844,659</b>	<b>1,375,041</b>	<b>935,609</b>	<b>810,075</b>	<b>388,973</b>
Value* (£).						
United Kingdom ...	31	—	—	—	1,383	—
Canada ...	65,120	80,519	98,672	131,675	159,464	80,727
Newfoundland and Labrador	502	—	—	—	6,917	—
<b>Total from British Possessions.</b>	<b>65,653</b>	<b>80,519</b>	<b>98,672</b>	<b>131,675</b>	<b>167,764</b>	<b>80,727</b>
Germany ...	699	—	—	—	—	—
Portugal ...	69,578	39,523	31,551	11,130	1,604	—
Spain ...	618,059	735,635	1,352,061	1,077,177	772,785	327,966
Cuba ...	4,423	—	—	—	—	44,133
Brazil ...	11,449	—	—	—	—	—
Japan ...	—	—	1,386	—	—	—
Other Countries ...	—	—	—	—	—	625
<b>Total from Foreign Countries</b>	<b>704,208</b>	<b>775,158</b>	<b>1,384,998</b>	<b>1,088,307</b>	<b>774,389</b>	<b>372,724</b>
<b>TOTAL ...</b>	<b>769,861</b>	<b>855,677</b>	<b>1,483,670</b>	<b>1,219,982</b>	<b>942,153</b>	<b>453,451</b>

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Calendar year.

### Cuba.

The island of Cuba possesses at least one substantial pyrites deposit, which has been worked for some years.

During the war development was very considerably extended, and a large quantity of mineral was shipped to destinations on the Atlantic sea-board of the United States in 1919.

### Peru.

Pyrites occurs abundantly in many of the copper deposits in the Cerro de Pasco mining district, and it is the chief gangue mineral in many of the copper veins in the Morococha and Casapalca districts. It is also found abundantly in the Colquijirca district, where many of the outcrops of the silver veins are composed almost entirely of pyrites.

Very little attention is given to the exploitation of these occurrences, and the only recorded production of pyrites during the period under review was 49 tons in the year 1916 and 149 tons in the year 1917.

### Japan.\*

The mining of pyrites has long been an established industry in Japan. The chief producing areas are situated in the district of Wakayama, in Hondu, where the pyrites occurs in lenticular masses about 5 to 6 feet in thickness, the ore containing about 2 per cent. of copper and about 45 per cent. of sulphur.

The Takara mine, situated about 5 miles south of Sasako station on the Chuwo line, is worked on a lens of pyrites about 240 feet in length with a thickness of about 90 feet, the mineral containing about 40 to 45 per cent. of sulphur with 1·6 to 1·7 per cent. of copper. The powdery nature of the pyrites detracts somewhat from its value for acid-making purposes.

Other producing mines are the Yanahara and the Hisagi in the Okayama district of Hondu, and the Kucho in the Ehime district of Shikoku.

Pyrites is also mined to a small extent in the island of Sakhalin.

#### *Production of Iron-pyrites in Japan.*

Year.	Quantity (long tons).	Value† (£).
1913	112,803	58,993
1914	113,984	60,061
1915	66,492	37,962
1916	89,609	76,739
1917	119,489	104,074
1918	104,120	108,384
1919	125,033	182,873

\* Annual Statistical Rept. of the Dept. of Agriculture and Commerce, Japan.

† Values converted to £ sterling at the rate of 1 yen = 2s.

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Borates	... (1920)	,,	9d.	(10½d.)
Coal, Coke and By-Products				
Part I	... (1921)	,,	3s. 6d.	(3s. 8½d.)
Part II	...	,,	<i>(in the press)</i>	
Chrome Ore and Chromium	(1920)	,,	1s.	(1s. 1½d.)
Cobalt	... (1921)	,,	9d.	(10½d.)
Felspar	... (1920)	,,	6d.	(7d.)
Fluorspar	... (1921)	,,	9d.	(10½d.)
Fuller's Earth	... (1920)	,,	6d.	(7d.)
Iron Ore Resources of the World.				
Parts I, II and III	...	,,	<i>(in the press)</i>	
Magnesite	... (1920)	,,	1s. 3d.	(1s. 4½d.)
Manganese	... (1921)	,,	3s. 6d.	(3s. 8½d.)
Mica	... (1921)	,,	9d.	(10½d.)
Monazite	... (1920)	,,	6d.	(7d.)
Nitrates	... (1920)	,,	9d.	(10½d.)
Phosphates	... (1921)	,,	2s.	(2s. 1½d.)
Sulphur and Iron-Pyrites	... (1922)	,,	1s. 6d.	(1s. 7½d.)
Talc	... (1921)	,,	9d.	(10½d.)
Tungsten	... (1921)	,,	1s.	(1s. 1½d.)
Zinc	... (1921)	,,	3s. 6d.	(3s. 8d.)
Statistical Summary (Production, Imports and Exports)	(1913-20)	,,	3s.	(3s. 2d.)



